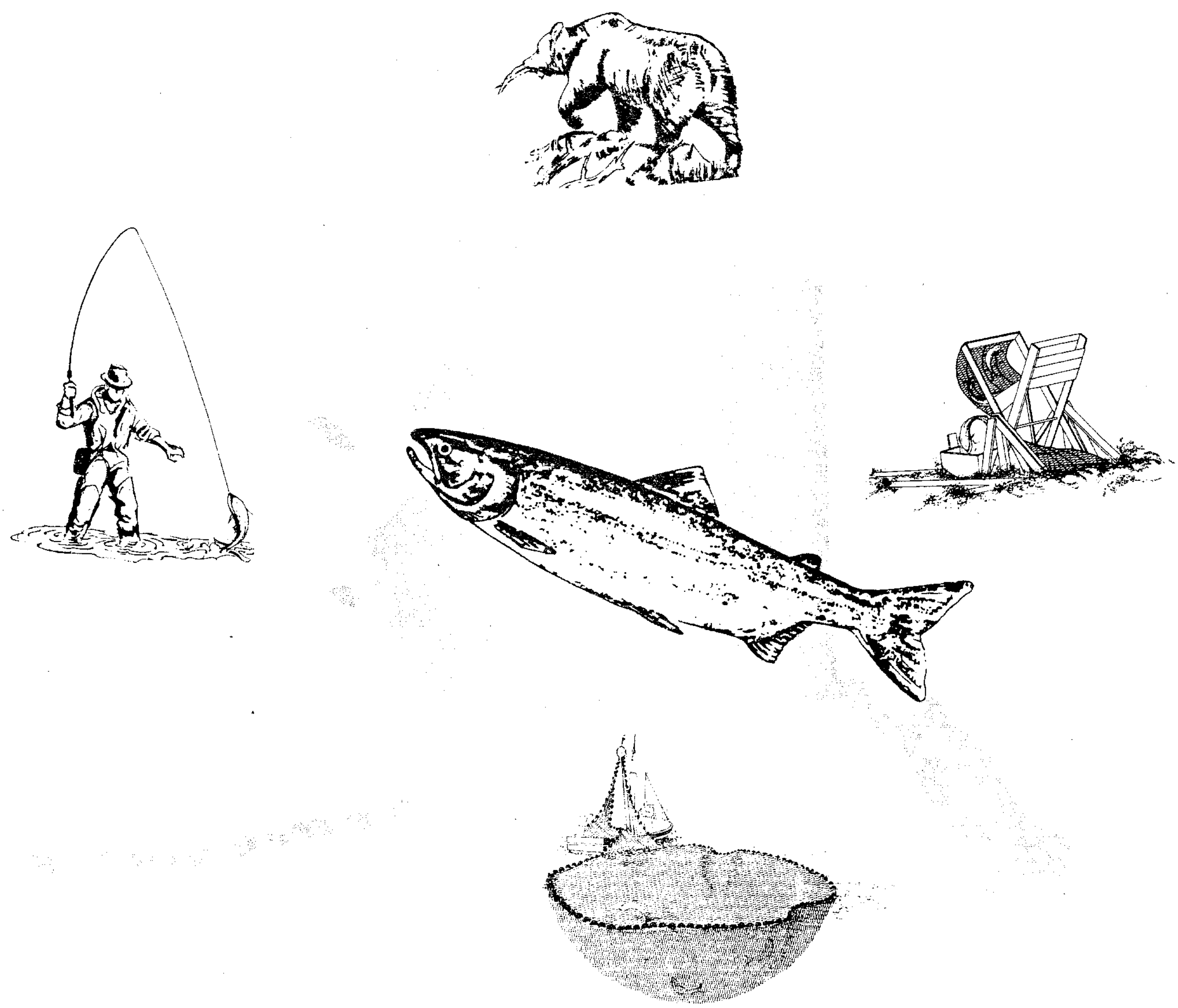
RUN TIMING AND ABUNDANCE OF ADULT SALMON IN THE TULUKSAK RIVER, YUKON DELTA NATIONAL WILDLIFE REFUGE, ALASKA, 1992

Alaska Fisheries Progress Report Number 95-3



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Run Timing and Abundance of Adult Salmon in the Tuluksak River, Yukon Delta National Wildlife Refuge, Alaska, 1992

Progress Report

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Abstract

A resistance board weir was used to collect run timing, abundance, and biological data from salmon in the Tuluksak River June 24-September 10, 1992. The run sizes of 11,183 chum *Oncorhynchus keta*, 1,083 chinook *O. tshawytscha*, 2,470 pink *O. gorbuscha*, 129 sockeye salmon *O. nerka*, and 7,501 coho *O. kisutch* were higher than 1991 counts. Peak weekly passages for salmon occurred: chinook, July 5-11; chum and sockeye, July 19-25; pink, August 9-15; and coho, August 23-29.

Other species counted included 232 Dolly Varden *Salvelinus malma*, 125 whitefish *Coregoninae* and *Prosopium* spp., 69 Arctic grayling, *Thymallus arcticus*, and 12 northern pike, *Esox lucius*. Whitefish moved primarily in September and Dolly Varden and Arctic grayling in July.

Aerial index surveys have rarely exceeded 5,000 chum salmon and 400 chinook salmon on the Tuluksak River and are useful as indicators of escapement. Stream-life for salmon above the weir was estimated as follows: chum 10 days, chinook 21 days, sockeye 29 days, and pink salmon 9 days. Stream-life for coho salmon was not estimated. Stream-life and daily passage data indicate that the optimal period for aerial surveys is the last week of July for chinook salmon and after the first of September for coho salmon. Chum salmon return over a longer period of time and aerial index surveys should be flown several times to estimate total abundance.

Sex ratios for salmon varied by week. Chum salmon females comprised 50% of the seasonal passage. Female chinook salmon comprised 14.9% of the seasons passage. The total passage of female chinook salmon was estimated at only 160 fish. Females comprised 43.2% of the coho salmon passage.

Gill net marks ranged from <1% on pink salmon to 20% for female chinook salmon sampled at the weir.

Migration rates between the test fishery at Bethel and the Tuluksak River weir were grossly estimated at; 9.4 km/d for chum and coho, 8.0 km/d for chinook and 6.8 km/d for sockeye salmon.

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Introduction

The Tuluksak River is one of several lower Kuskokwim River tributaries on the Yukon Delta National Wildlife Refuge (Refuge). Located at river kilometer (rkm) 218 on the Kuskokwim River, the Tuluksak River provides important spawning and rearing habitat for chinook *Oncorhynchus tshawytscha*, chum *O. keta*, sockeye *O. nerka*, pink *O. gorbuscha*, and coho *O. kisutch* salmon (Alt 1977; U.S. Fish and Wildlife Service 1992). Salmon escapements provide food for brown bears *Ursus arctos* and other carnivores, raptors, and scavengers. In addition, resident fish and salmon fry rely heavily on the nutrient base provided by salmon carcasses (U.S. Fish and Wildlife Service 1992). Salmon from these lower Kuskokwim River tributaries also contribute to one of the largest and most intense subsistence salmon fisheries in Alaska, and pass through two commercial fishery districts between the mouth and the Tuluksak River (Francisco et al. 1992; U.S. Fish and Wildlife Service 1988, 1992).

Managing the Kuskokwim River for sustainable harvests requires that individual tributaries receive adequate escapements. Harvest management is complicated by the mixed stock nature of the lower Kuskokwim River fishery. Harvest level guidelines for the current year are determined from test and commercial fishery catch data indices at Bethel and from lower river commercial fishery harvests. Managers attempt to distribute catch through time to avoid over harvesting species and stocks returning to one of the 11 major and numerous minor tributaries of the Kuskokwim River. Distribution of the catch is necessary because each stock may have a characteristic migratory timing (Mundy 1982). Stocks or species returning in low numbers may be over harvested incidentally during extended harvesting of abundant stocks. Data are lacking on many of these individual stocks in the Kuskokwim River drainage and are needed for better management.

The majority of the chinook salmon harvest occurs in the lower Kuskokwim River below Tuluksak. Harvest on the lower Kuskokwim River increased from 1985 to 1992 and ranged from 35,443 to 68,018 in the subsistence fishery and from 18,171 to 51,656 in the commercial fishery (Francisco et al. 1993). A conservation concern developed in the mid 1980's when escapements were low. Low escapements were further compounded by the low number of female chinook salmon in the escapement. The Alaska Department of Fish and Game (Department) reduced the average yearly commercial harvest of females from 42.8% to 31% by reducing gill net mesh size from >20.3 cm to ≤15.2 cm (Francisco et al. 1994). The number of gillnet marked females at escapement projects increased after the mesh size change (Doug Molyneaux, Alaska Department of Fish and Game, personal communication). Escapements continued to decline prompting the Department to eliminate the directed commercial harvest of chinook salmon. Harvest of surplus fish was reserved for the priority subsistence fishery. Elimination of the directed commercial harvest and restriction of the mesh size during the chum salmon fishery helped to rebuild stocks to escapement objective levels. Chinook salmon currently harvested in the commercial fishery are those taken incidentally during the directed chum salmon openings.

Commercial harvests of chum salmon have exceeded 200,000 every year since 1975, reached a record of 1,327,006 in 1988 and declined to 436,506 in 1992. Coho salmon commercial harvests have grown from less than 50,000 fish in the early 1960's to over 450,000 fish during most years since 1985. Subsistence users from villages in the lower Kuskokwim River harvested an estimated 25,083 coho salmon and 53,783 chum salmon in 1992. From 1974 to 1992 even year pink salmon commercial harvests have ranged from 16,569 to 85,978.

Chum and chinook salmon abundances in the Tuluksak and other tributary rivers on the Refuge have been estimated on an opportunistic basis by the Department using aerial index surveys (Schneiderhan 1983, 1988; Francisco et al. 1992). These aerial index surveys generally underestimate escapements and are conducted after the majority of the salmon are on the spawning grounds. This timing does not allow for harvest adjustments which allow additional escapements to reach the spawning grounds. Weather delays and poor visibility make some aerial index surveys of questionable value. Aerial index surveys do not gather age, sex, and size composition data, which are used to determine escapement quality. The Refuge has supported these aerial index surveys in recent years with aircraft and pilots because it represents the best data available for several tributaries and gives an index of the escapement. Information to determine optimal aerial index survey timing for refuge rivers has not been collected.

Chinook and chum salmon aerial index counts on the Tuluksak River have been below 50% of the aerial index objective for most years (Appendix 1). Coho salmon escapement objectives have not been set for rivers on the Refuge because limited escapement data have been collected. Additional biological data, therefore, needs to be gathered to maintain sustainable populations of coho salmon.

The Department has gathered limited fishery data on lower Kuskokwim River drainages on the Refuge. In 1978, a sonar project was tried on the Kwethluk River but was dropped after high debris loads gave false readings (Schneiderhan 1979). The Department currently operates two salmon escapement projects, the Aniak River sonar and Kogrukluk River weir. Both projects are located above the commercial fishery at about 378 and 781 rkm from the mouth of the Kuskokwim River (Figure 1). Spawning escapement counts from the Aniak River sonar, Kogrukluk River weir, and catches in the Bethel test fishery, and lower Kuskokwim River commercial and subsistence fisheries are used to make management decisions. These decisions effect escapements to all tributaries including those on the Refuge.

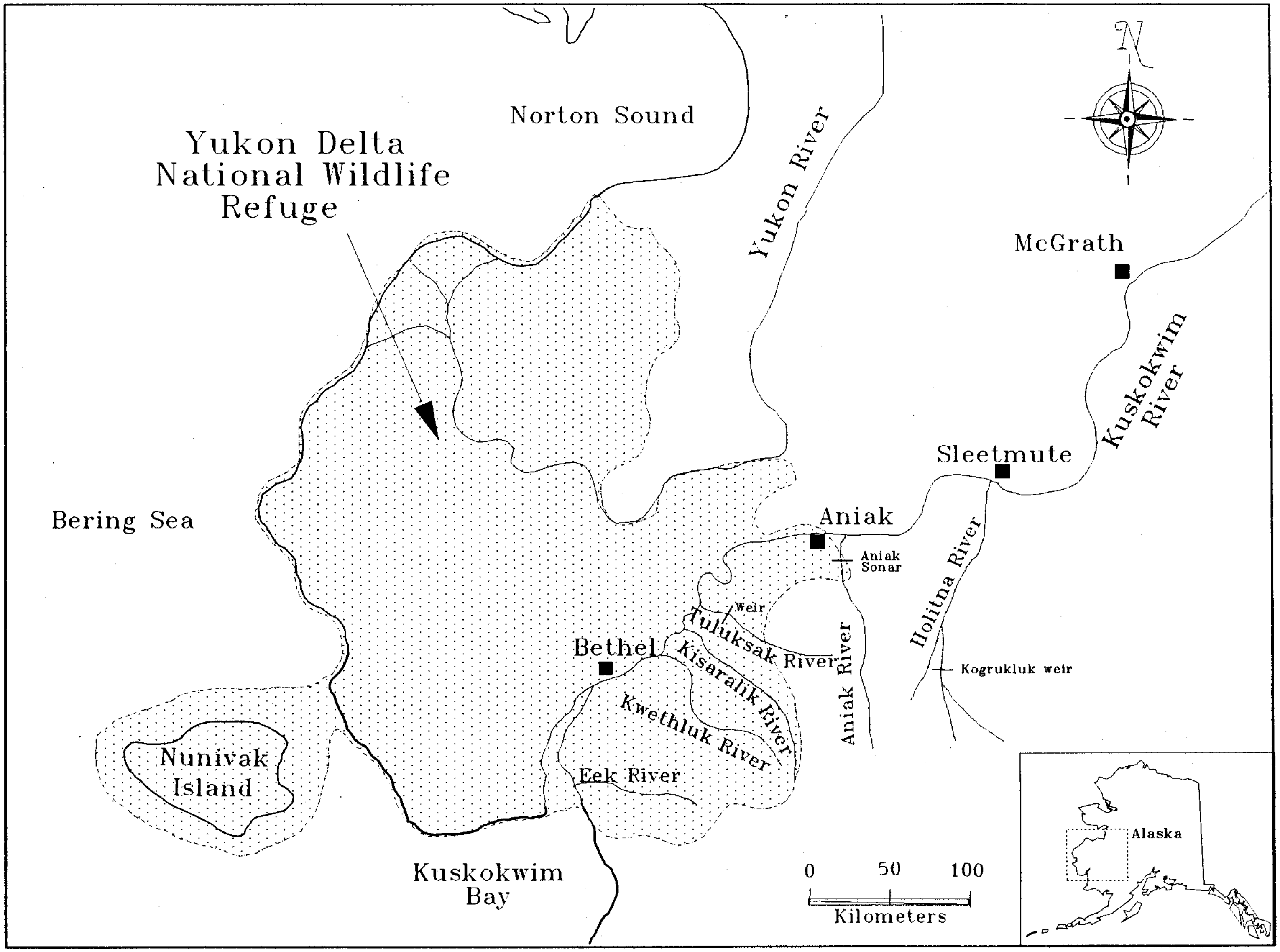

FIGURE 1.–Lower Kuskokwim River tributaries on the Yukon Delta National Wildlife Refuge, Alaska, 1992.

The Alaska National Interest Lands Conservation Act mandates that, within the Refuge, salmon populations and their habitats be conserved. Refuge mandates, however, may not be met without conservative management practices since reliable data on lower tributary fish stocks are missing. Salmon escapement monitoring for lower Kuskokwim River tributaries on the Refuge are ranked as priority projects in the Refuge Fishery Management Plan by the U.S. Fish and Wildlife Service (Service) and the Department (U.S. Fish and Wildlife Service 1992).

As the human population in regional villages expands, the need for accurate escapement data from the lower Kuskokwim River tributaries on the Refuge will increase. In 1991, a multi-year study was started by the Service to: (1) estimate daily salmon escapements in the Tuluksak River; (2) quantify the salmon age, sex, and length composition; (3) estimate migration time between the test or commercial fishery and the weir; (4) monitor gillnet marks on salmon; (5) estimate optimal timing to gather aerial index survey data; (6) count other species passing through the weir.

Study Area

The Tuluksak River is located in the lower Kuskokwim River drainage (Figures 1, 2). The region has a subarctic climate characterized by extreme temperatures. Summer temperatures average a high of 15°C and average winter lows are near -12°C (Alt 1977). Average yearly precipitation is about 50 cm with the majority falling between June and October. River break-up occurs in early May and freeze-up occurs in late November.

The Tuluksak River starts in the Kilbuck Mountains, flows northwest approximately 137 km, and drains an area of about 2,098 km^2. The Fog River is the only major tributary to the Tuluksak River, and enters in the lower section (Figure 2). The Tuluksak River is a slow moving, meandering stream over most of its length, cutting through several tundra areas in its lower section (Alt 1977). Gravel bottoms and cut banks with overhanging vegetation predominate in the upper sections of the river. Water clarity in the upper section is 1-2 m during low water. The lower section is characterized by deep channels that are mud lined and the water is turbid.

Gold dredging operations near the mining camp of Nyac since the early 1900's have extensively changed the drainage above the refuge boundary (Crayton 1990; Francisco and Sundberg 1983). Dredging activity is now confined to Bear Creek, a tributary to the Tuluksak River above the Refuge boundary, but may be expanded.

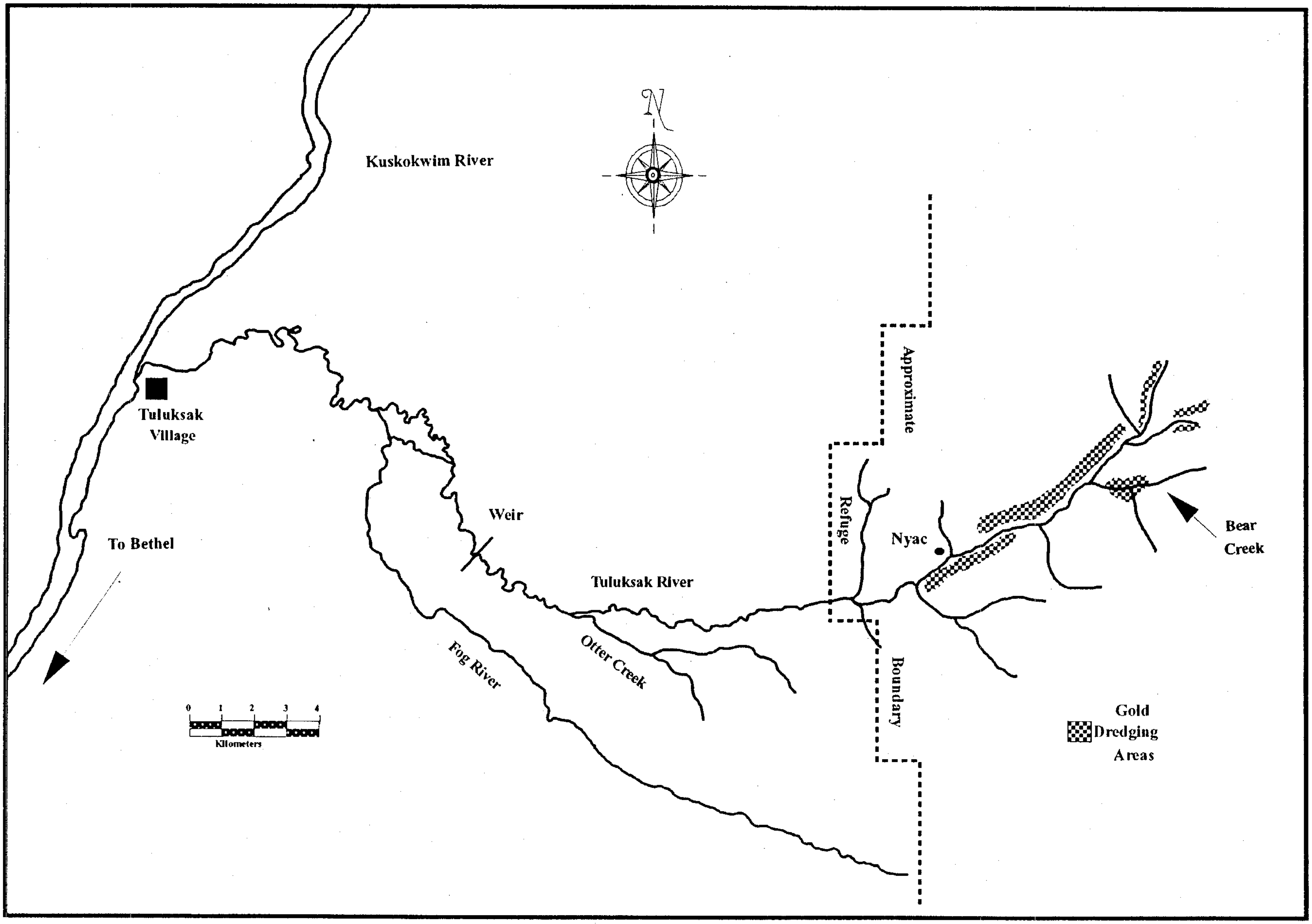

FIGURE 2.–Fish weir location on the Tuluksak River, Alaska, 1992.

Methods

Weir Operation

A resistance board weir with picket spacing of 3.5 cm spanning 48 meters of river (Tobin 1994) was installed at rkm 76 (N 60°, 59', 160°, in the Tuluksak River during June 1992. The weir was operated from June 24 to September 10, 1992. A staff gauge was installed on the back side of the bulkhead and daily water levels were recorded at 0800 hours each day. Stream discharge was estimated using the method described by Hamilton and Bergersen (1984) with a Marsh-McBirney (Model 201-D) flow meter and top setting wading rod. Water temperatures were measured daily during the middle of the day.

All fish were identified to species, counted, and noted for gill net marks as they passed through the weir. The trap was usually opened at 0700 hours and closed at midnight or earlier depending on the day length. The weir was checked for holes and cleaned daily before 0900 hours. Snorkeling was used to check weir integrity and substrate conditions. Cleaning consisted of walking across each panel until it was partially submerged and letting the current wash the debris downstream. Algal growths were removed by scrubbing with long handled brooms. Spent salmon and carcasses (carcasses) washing up on the weir were counted, identified to species and passed downstream at four hour periods during routine cleaning operations.

Biological Data

Sample weeks or strata started on Sunday and ended the following Saturday. A weekly quota of 160 chum, 140 chinook and 110 coho salmon was sampled at the beginning of each week. Samples were collected in as short a period (1-3 days) as possible to approximate a pulse or snapshot sample (Geiger et al. 1990). All fish within the trap were sampled to prevent bias. A seasonal quota of 40 pink salmon was sampled throughout the season. Once weekly quotas were obtained, the trap was opened and fish were passed until the next sampling period.

Sampled fish were measured, weighed, scales collected for aging, identified to sex using external characteristics, and released upstream. Salmon were measured to the nearest 5 mm mid-eye to fork length and weighed to the nearest 100 g. Gill net marks were noted on each fish. Scales were removed from the preferred area for age determination (Koo 1962; Mosher 1968). One scale was taken from chum and sockeye salmon and four were taken from chinook and coho salmon. Scale impressions were made on cellulose acetate cards using a heated scale press and examined with a microfiche reader. Salmon ages were reported according to the European Method (Koo 1962).

All salmon were aged by two readers. Ages were verified through comparison to commercial catch samples aged by a Department biologist. Mean lengths of males and females by age were compared using a two-tailed t-test at the α=0.05 level (Zar 1984)

Age and sex composition of the weekly weir passage were estimated using a stratified sampling design (Cochran 1977). Strata were pooled if sufficient samples were not obtained in a single stratum. Age composition and associated variances for weekly passage were calculated as:

$$\hat{A}_h = N_h \hat{p}_h; \tag{1}$$

$$\hat{V}[\hat{A}_h] = N_h^2 \left(\frac{\hat{p}_h (1-\hat{p}_h)}{n_h - 1} \right); \tag{2}$$

$\hat{A}_h$= the estimated number of fish of a given age and sex during week h,

N_h= the number of fish passing in week h,

$\hat{P}_h$= the proportion of sample in week h of a given age,

n_h= the number of fish in sample for week h.

Weekly abundance estimates and their variances were summed to obtain age and sex composition estimates for the season as follows:

$$\hat{A}_{st} = \sum \hat{A}_h; \tag{3}$$

$$\hat{V}[\hat{A}_{st}] = \sum \hat{V}(\hat{A}_h); \tag{4}$$

where:

$\hat{A}_{st}$= the estimated number of fish of a given age for the season.

A Z-test comparing the proportion of one sex's age to another was used to determine if age composition differed between the sexes.

Proportions within each sex for a given age was calculated as:

$$\hat{p}_{ij} = \frac{\hat{A}_{st,ij}}{\hat{A}_{st,i}}; \tag{5}$$

where:

i = sex,

j = age,

$\hat{A}_{st,ij}$ = estimated number of fish of sex i and age j, and

$\hat{A}_{st,i}$ = estimated number of fish of sex i.

The variance was calculated as:

$$\hat{V}(\hat{p}_{ij}) = \hat{p}_{ij}^2\left(\frac{\hat{V}(\hat{A}_{st,ij})}{\hat{A}_{st,ij}^2} + \frac{\hat{V}(\hat{A}_{st,i})}{\hat{A}_{st,i}^2}\right); \tag{6}$$

where the variances are the variances calculated per equation (4).

The proportions were considered different if Z was greater than the critical value from a Z-table. Z was calculated as:

$$Z = \frac{\hat{p}_{ij} - \hat{p}_{i'j}}{\sqrt{\hat{V}(\hat{p}_{ij}) + \hat{V}(\hat{p}_{i'j})}}; \tag{7}$$

where:

i' = the other sex.

The sample size was assumed to be large enough to use the Z-distribution. Applying the Bonferroni adjustment, P was significant at the α=0.05 level if $P<0.05/k$, where k was the number of age groups. Age composition was considered different if the proportions for at least one age group differed between the sexes ($P<0.05/k$).

Migration Rates

Migration rate in days for each salmon species to pass between the test fishery and the weir was estimated. The estimate was equal to the difference between the 50% cumulative passage dates at each location. Cumulative passage at the Bethel test fishery was considered to be equal to the cumulative catch per unit of effort. I assumed that fish bound for the Tuluksak River were not temporally separated but equally represented in test fishery sampling.

Stream-life, the amount of time each salmon species spends (residence time) above the weir before washing downstream was similarly estimated. Stream-life was assumed to be the difference between the 50% cumulative passage dates of upstream migration and the downstream passage of carcasses.

Results

Weir Operation

Water levels remained low for most of the year. Peak water on September 7 and 8 submerged several panels 3-5 cm under the water (Appendix 2). No fish were observed to pass over the weir during this time period. Temperatures exceeded 10°C for 57 days in 1992. The maximum temperature was 14°C for 18 days in late July and early August. Discharge was measured on September 4 at 30.47 m^3/s.

Biological Data

A total of 11,183 chum, 1,083 chinook, 2,470 pink, 129 sockeye, and 7,501 coho salmon passed through the weir between June 24 and September 10, 1992 (Figure 3, Appendix 3 and 4). Salmon carcasses passing downstream over the weir consisted of 3,801 chum, 327 chinook, 1,373 pink, 38 sockeye and 4 coho salmon (Appendix 5). Other species passing through the weir included 232 Dolly Varden *Salvelinus malma*, 125 whitefish *Coregonus* and *Prosopium spp.*, 69 Arctic grayling *Thymallus arcticus*, and 12 northern pike *Esox lucius* (Figure 4).

Chum salmon.-Chum salmon was the first salmon species counted and passed through the weir on June 24. Peak passage (N=2,979) occurred the week of July 19-25 (Figure 3, Appendix 6). Fifty percent of the migration passed the weir by July 21, 27 days after the first chum salmon passed through the weir (Figure 5, Appendix 4).

Scale samples of 1,163 chum salmon from the escapement were useable and aged. The passage was composed of 50% females and 50% males distributed among age classes 0.2, 0.3, 0.4, and 0.5 (Table 1, Appendix 6). Age composition of males and females differed (Appendix 6, P<0.0125 for age 0.3, 0.4, and 0.5 fish). Age 0.3 fish composed 51.6% of the run and was predominately females. Age 0.4 composed 44.5% of the run and was predominately males. Age 0.4 chum salmon predominated in the weekly passage until the week of July 19-25, when age 0.3 fish predominated (Appendix 6).

Lengths of males were longer than females in all age groups (two-tailed t-test age 0.2, t=8.18, df=34, P=0.001); age 0.3, t=11.19, df=661, P=0.001; age 0.4, t=14.08, df=573, P=0.001; age 0.5, t=2.45, df=21, P=0.023). Weights ranged from 1,200 to 5,600 g (Table 1). Females made up 50% of the run (Appendix 6). Females initially

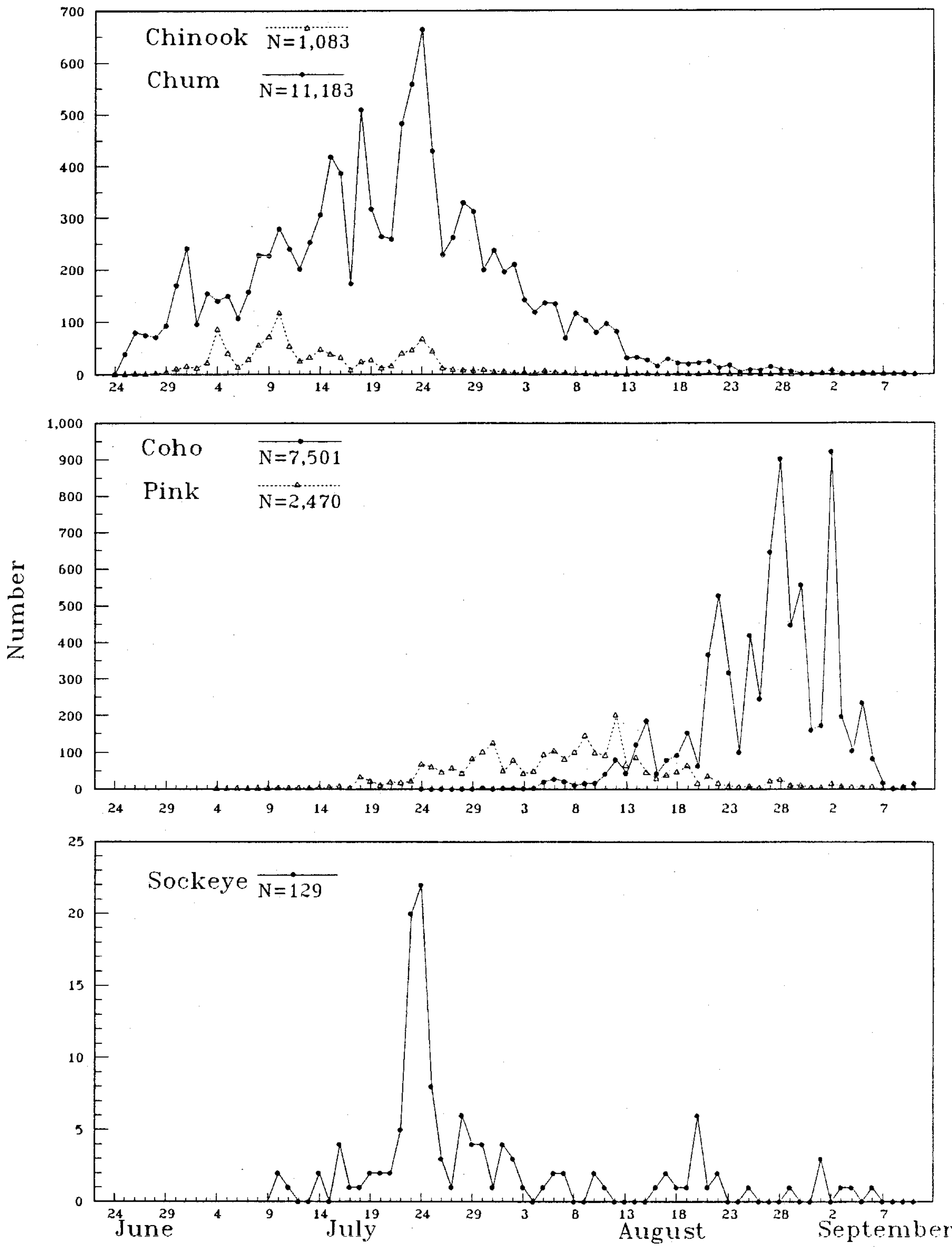

FIGURE 3.-Salmon counted through the Tuluksak River weir, Alaska, June 24 to September 10, 1992.

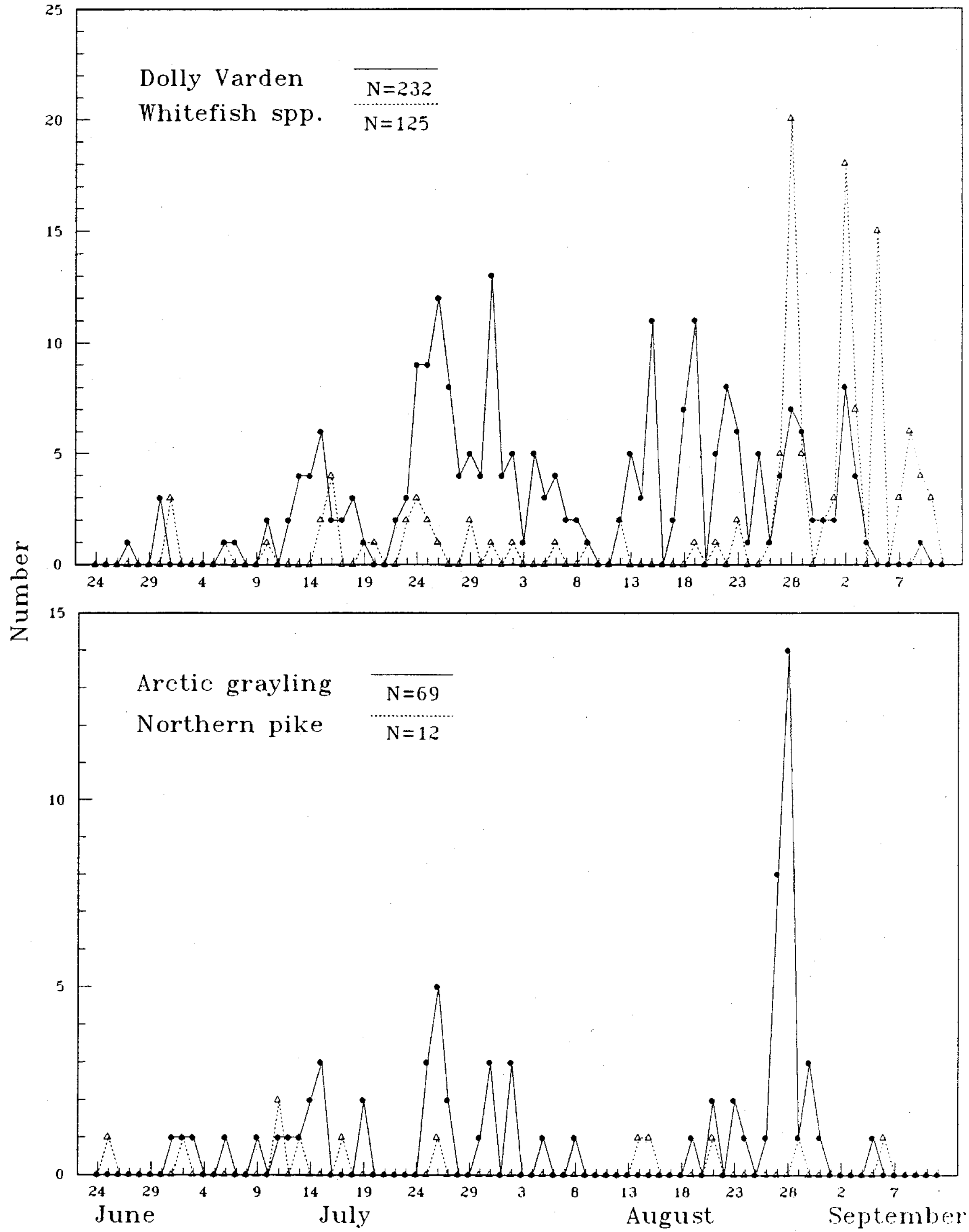

FIGURE 4.-Resident fish counted through the Tuluksak River weir, Alaska, June 24 to September 10, 1992.

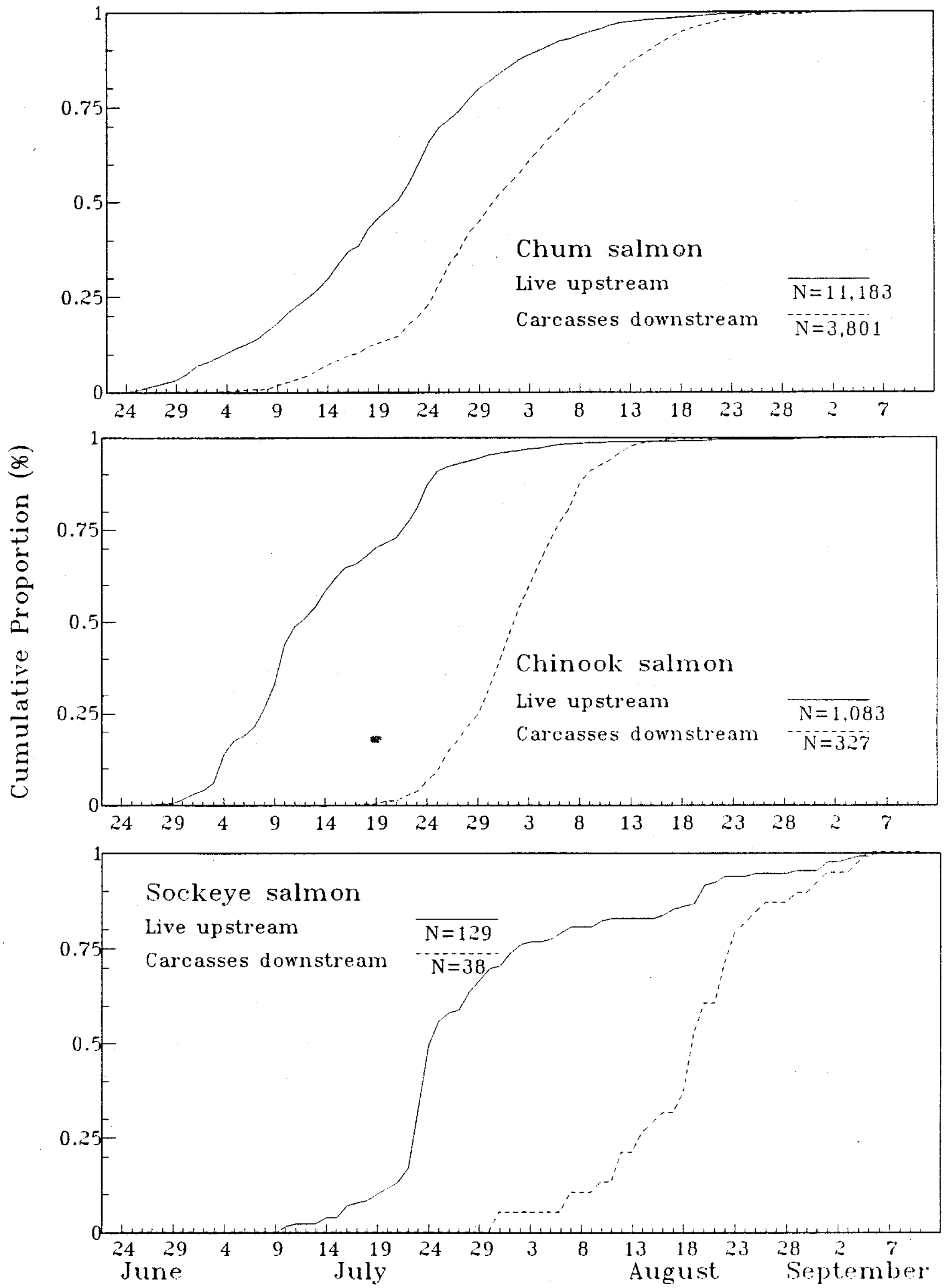

FIGURE 5.-Comparison of cumulative salmon upstream passage and fish carcasses passed downstream, Tuluksak River weir, Alaska, 1992.

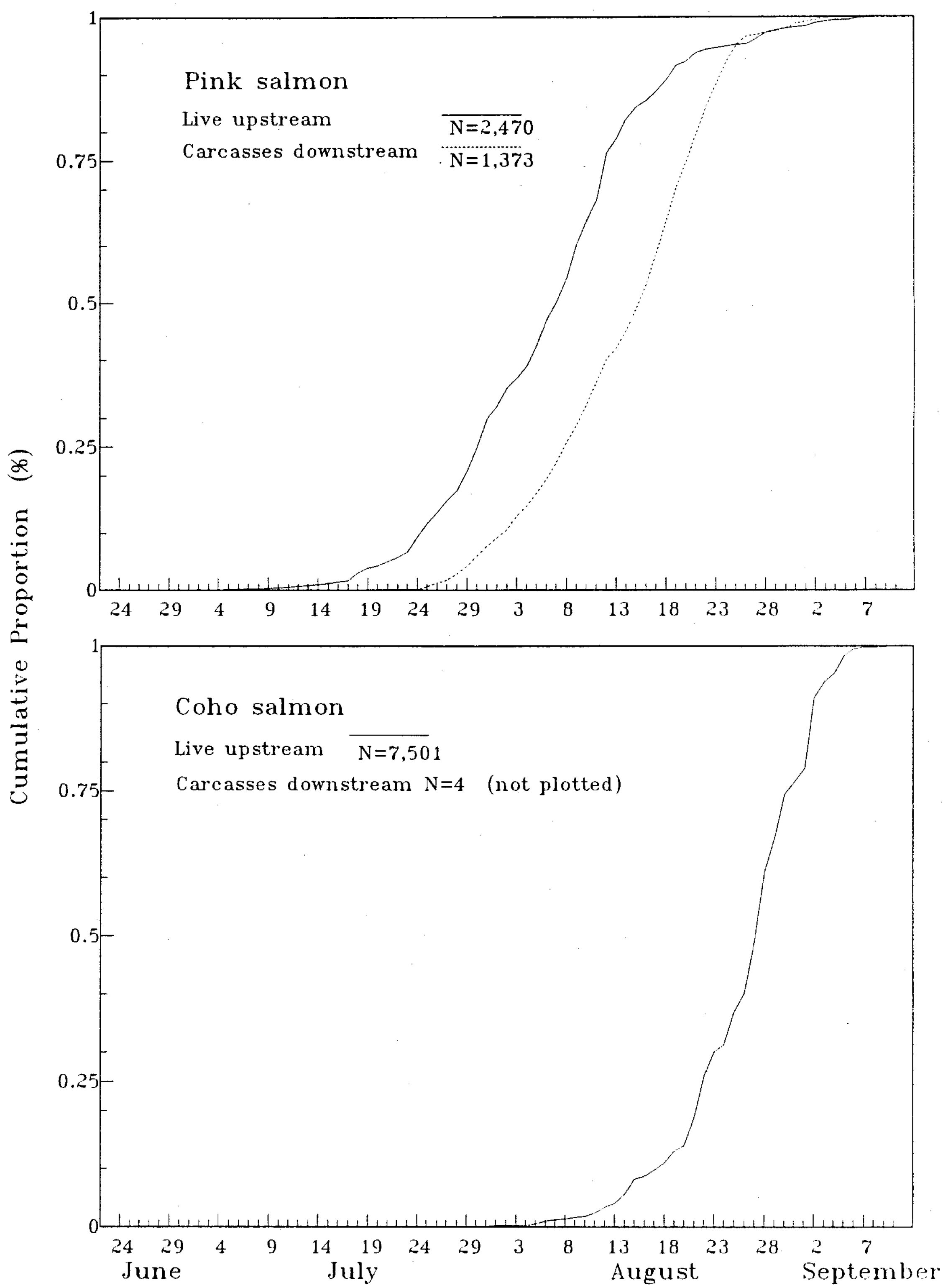

FIGURE 5.-(Continued).

comprised less than 50% of the run, but predominated after July 19 (Figure 6).

Gill net marks (N=398) were observed on 4% of the chum salmon passing the weir (Appendix 3). The first carcass was observed on June 25. Fifty percent of the carcasses were passed downstream by July 31, 36 days after the first carcass was passed and 10 days after 50% of the upstream migration had occurred (Figure 5).

TABLE 1.-Age, length (mid-eye to fork length) and weight composition of chum salmon sampled at the Tuluksak River weir, Alaska, 1992.

		Length (mm)			Weight (g)		
Age	N	Mean	SE	Range	Mean	SE	Range
				Female			
0.2	18	506	7.1	455-570	2,014	91	1,600-3,000
0.3	395	529	1.6	425-650	2,414	28	1,200-4,200
0.4	228	548	2.0	450-625	2,698	32	1,500-4,000
0.5	3	558	6.8	550-570	2,767	260	2,300-3,200
Total	645	535	1.3	425-650	2,504	21	1,200-4,200
				Male			
0.2	18	505	7.4	505-628	2,100	136	2,100-4,800
0.3	268	559	2.3	435-660	3,167	42	1,600-5,600
0.4	347	588	2.0	440-890	3,661	35	1,600-5,500
0.5	20	599	6.3	550-645	3,760	135	2,900-4,900
Total	653	577	1.54	435-890	3,460	28	1,600-5,600

Chinook salmon.-Chinook salmon passed the weir starting June 26 two days after the first chum salmon. Peak passage (N=377) occurred the week of July 5-11 (Figure 3). Fifty percent of the migration passed the weir by July 12, 16 days after the first fish passed.

Scale samples of 535 samples from the escapement were useable and aged. The escapement was composed of 14.9% female and 83.1% males distributed among seven age groups (Table 2). Males in age groups 1.2 and 1.3 were estimated to compose 37.5% and 30% of the escapement (Appendix 7). The majority of the females were in age groups 1.3 and 1.4 which made up 10.1% and 2.7% of the escapement. Only males were found with two years of freshwater growth.

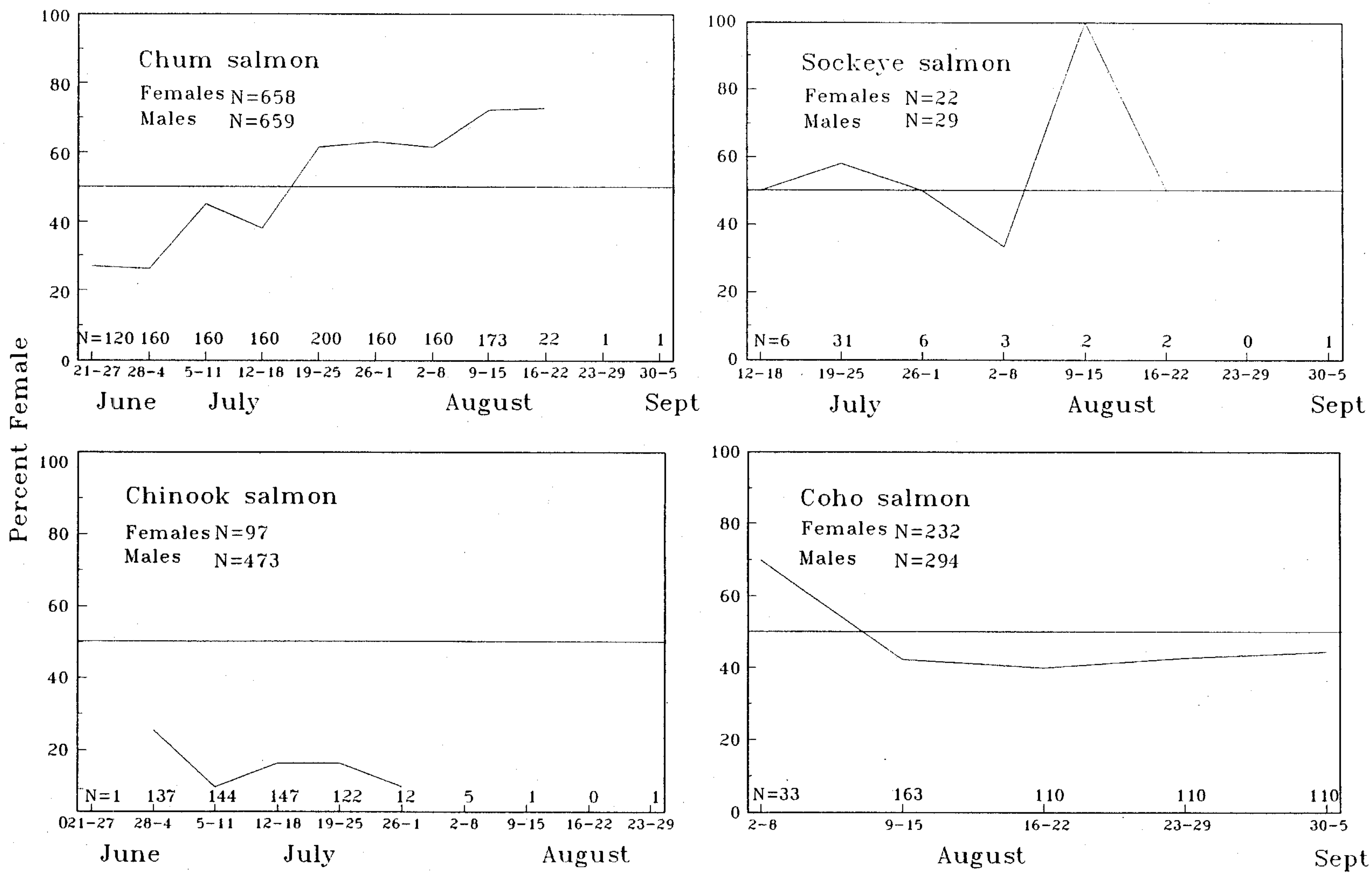

FIGURE 6.—Weekly sex composition (%) of female salmon sampled at the Tuluksak River weir, Alaska, 1992.

TABLE 2.-Age, length (mid-eye to fork length) and weight composition of chinook salmon sampled at the Tuluksak River weir, Alaska, 1992.

		Length (mm)			Weight (g)		
Age	N	Mean	SE	Range	Mean	SE	Range
				Female			
1.2	7	546	12.9	489 - 587	2,929	225	2,000- 3,600
1.3	15	762	17.3	657 - 875	7,660	531	4,300-11,500
1.4	58	875	7.1	621 - 990	11,933	277	4,500-16,400
1.5	7	935	14.7	864 - 978	13,786	587	10,700-15,500
Total	87	834	12	489 - 990	10,621	374	2,000-16,400
				Male			
1.1	43	395	3.5	349 - 466	1,100	42	600- 2,100
1.2	191	539	4.5	372 - 775	2,791	72	900- 7,500
1.3	168	682	4.9	492 - 905	5,502	122	2,300-11,100
1.4	32	838	19.3	610-1,055	10,716	810	3,300-22,500
1.5	2	896	94.0	802 - 990	12,450	4,750	7,700-17,200
2.2	2	520	23.3	400 - 630	2,530	346	1,000- 4,200
2.3	2	637	52.5	585 - 690	4,650	1,150	3,500- 5,800
Total	448	602	6.1	349-1,055	4,261	140	600-22,500

Age composition of males and females differed (Appendix 7, $P<0.007$ for age 1.1, 1.2, 1.3, 2.2, and 1.4 fish). Female lengths were significantly longer than males in ages 1.3 and 1.4 (two-tailed t-test age 1.3 $t=4.65$, df=181, $P<0.001$, age 1.4, $t=2.124$, df=88, $P=0.036$). Lengths of both sexes were similar for age 1.2 (two-tailed t-test $t=0.03$, df=196, $P=0.762$). Data was insufficient for other length comparisons.

Female numbers dropped from 25% (June 28-July 4) to approximately 10% of the run July 5-11 before rebounding to 18% July 12-25 (Figure 6). Females comprised only 14.8% of the total chinook salmon passage (Appendix 7). Estimated female spawners based upon the weighted weekly passage was only 160 for the year.

Gill net marks were observed through out the season and were observed on approximately 20% of the females and 10% ($N=101$) of the total chinook salmon passing the weir (Appendix 3). The number of gill net marks found on females differed from the number found on males ($X^2=12.55$, df=1, $P=0.001$).

Carcasses were first observed on the weir July 18, 22 days after the first chinook salmon was passed upstream (Figure 5). Fifty percent of the carcasses had passed downstream by August 2, 15 days after the first carcass was passed and 21 days after 50% of the upstream migration had occurred.

Pink salmon.-Pink salmon passed the weir starting July 3 and continued until September 10 (Figure 3). Peak passage (N=733) occurred the week of August 9-15. Fifty percent of the migration had passed by August 7, 35 days after the first pink salmon was passed (Figure 5).

Twenty-five pink salmon were weighed, measured, and sexed. Lengths ranged from 384 to 452 mm, and weights ranged from 1,100 to 2,300 g for both sexes. Females (N=9) averaged 418 mm and 1,383 g and males (N=16) averaged 420 mm and 1,500 g. Lengths were similar between sexes (two-tailed t-test t=0.285, df=23, P=0.78). Gill net marks were observed on 7 pink salmon passing the weir.

Pink salmon carcasses were passed downstream starting July 22 (Figure 5). Fifty percent were passed downstream by August 16, 25 days after the first carcass was passed and 9 days after the 50% of the upstream migration had occurred (Figure 5).

Sockeye salmon.-Sockeye salmon passed the weir starting July 10 and continued until September 6 (Figure 5). Peak passage (N=61) occurred the week of July 19-25. Fifty percent of the migration had passed by July 25, 14 days after the first sockeye salmon passed upstream (Figure 5, Appendix 4).

Ages were obtained from 29 of the 52 sockeye salmon sampled at the weir. Females and males composed 43% and 57% of the samples and ages were distributed among four ages 0.2, 0.3, 1.2, 1.3 (Table 3). Age 1.3 was the most prevalent age found. Mean lengths of males were longer than females for age 1.3 (two-tailed t-test t=5.86, df=22, P<0.001).

Gill net marks (N=5) were observed on approximately 4% of the sockeye salmon passing the weir. Sockeye salmon carcasses were passed downstream over the weir beginning July 20 (Figure 5). Fifty percent of the passage occurred August 19, 19 days after the first carcass was passed, and 29 days after the 50% of the upstream migration had occurred.

Coho salmon.-Coho salmon passed the weir starting July 23. Peak passage occurred the week of August 23-29 when 3,082 were passed (Figure 5). The second highest peak occurred August 30-September 5 with a passage of 2,354. Coho salmon were still passing the weir at the daily rate of 16 fish on September 10, the day before the weir was removed. Fifty percent of the coho salmon had passed the weir by August 28, 36 days after the first coho salmon was passed (Figure 5).

TABLE 3.-Age, length (mid-eye to fork length) and weight composition of sockeye salmon sampled at the Tuluksak River weir, Alaska, 1992.

		Length (mm)			Weight (g)		
Age	*N*	Mean	SE	Range	Mean	SE	Range
				Female			
0.3	1	505	-		2,400	-	-
1.2	2	515	15	500-530	2,800	600	2,200-3,400
1.3	8	541	7.4	505-565	2,694	90	2,200-3,000
Total	11	533	7.1	500-565	2,680	108	2,200-3,400
				Male			
0.2	1	540	-	-	2,900	-	-
1.2	1	495	-		2,300	-	
1.3	16	589	4.4	560-620	4,069	135	2,700-5,000
Total	18	581	6.9	495-620	3,906	165	2,300-5,000

A total of 526 coho salmon were sampled and 473 were aged (Table 4). The passage was composed of 43.2% females and 56.8% males distributed among 3 age classes, 1.1, 2.1, and 3.1. Age composition differed between sexes (Appendix 9, P=0.0125 for age 1.1 fish). Age 2.1 dominated the three age groups of males (76%) and females (81%) passing the weir. Other ages present were 1.1 and 3.1. Lengths were similar between sex's for age 1.1 (two-tailed t-test, t=1.624, df=32, P>0.114). The percentage of females (44.7%) differed significantly from males (X^2=84.47, df=1, P<0.01). Females made up less than 50% of the weekly passage throughout the season, except during the week of August 2-8, when they comprised 70% of the sample (Figure 6, Appendix 9). Gill net marks (N=404) were found on 5% of the coho salmon passed.

Because only four coho salmon carcasses were passed downstream over the weir, stream-life above the weir was not estimated.

Migration Rates

The difference between the 50% passage dates at the test fishery and at the weir for salmon was: 18 days for chum, 21 days for chinook, and 18 days for coho (Figure 7). Pink and sockeye salmon data were not plotted. Using the day when 50% of the salmon had passed both the test fishery and the weir, estimated salmon swimming speeds in km/d were: 9.4 for chum, 8 for chinook, 6.8 for sockeye, and 9.4 for coho salmon.

TABLE 4.-Age, length (mid-eye to fork length) and weight composition of coho salmon sampled at the Tuluksak River weir, Alaska, 1992.

		Length (mm)			Weight (g)		
Age	*N*	Mean	SE	Range	Mean	SE	Range
				Female			
1.1	10	554	10.6	476-598	2,930	195	1,600-3,600
2.1	172	563	3.0	423-689	3,044	48	1,100-4,500
3.1	31	566	6.2	449-630	3,148	94	2,000-4,500
Total	260	563	2.7	423-689	3,050	42	1,100-4,500
				Male			
1.1	24	524	10.9	415-614	2,452	179	900-4,100
2.1	198	536	3.7	396-644	2,741	66	900-5,600
3.1	38	566	7.1	454-640	3,236	147	1,750-5,000
Total	294	539	3.0	396-644	2,787	58	900-5,600

The run timing for 90% of each salmon species to pass the weir varied as follows: 43 days for chum, 30 days for chinook, 48 days for pink, 42 days for sockeye, and 42 days for coho salmon.

Discussion

The spacing between pickets (3.5 cm) may have allowed smaller fish to pass through undetected. Some resident fish which moved into the trap moved freely through the pickets when an attempt was made to net them. Smaller pink salmon may also have passed through the pickets undetected, although none were seen. Identification of whitefish to species was difficult and most were only classified as whitefish. Capture and individual examination was necessary for species identification.

The count data from this project do not include salmon returning to the Fog River or several small tributaries located below the weir. Because the proportion of females in the escapement is important for chinook salmon production, a monitoring facility such as a weir is needed to gather that type of data.

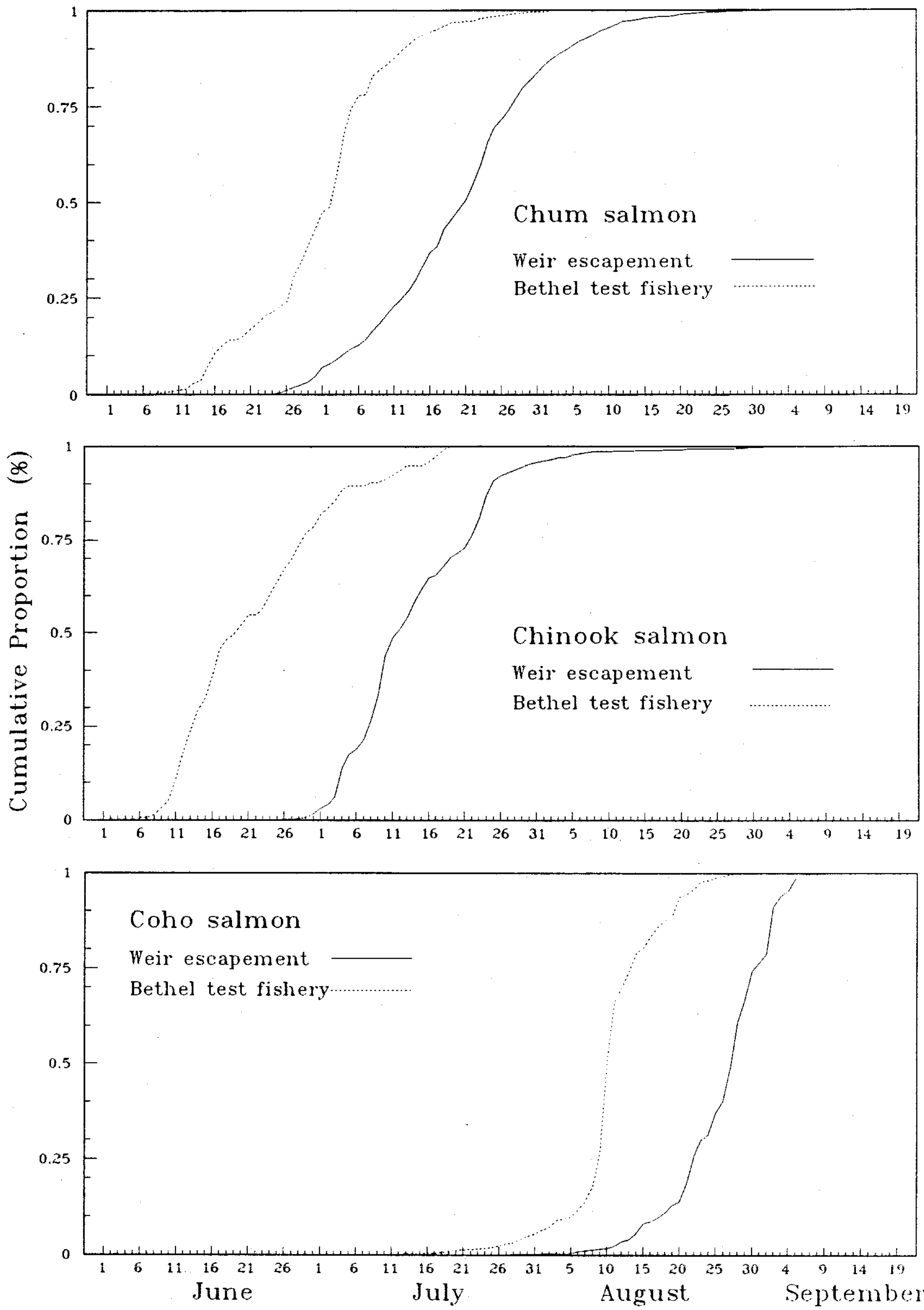

FIGURE 7.-Cumulative daily passage at the Tuluksak River weir, and cumulative daily catch per unit of effort at the Bethel test fishery, Alaska, 1992.

During high water flow on September 7 and 8, several panels were submerged 3-5 cm under the surface. This was primarily the result of an accumulation of debris on the lower sections of the panels that could not be cleaned off during high water. Water flows in September were near the maximum that the weir could pass without submerging. No fish were observed passing over the weir during this event.

Biological Data

Chum salmon.-The 1992 run of chum salmon (*N*=11,183) was 45% larger than the 7,675 reported in 1991 (Harper 1995). The larger return of chum salmon to the Tuluksak River was probably the result of an overall larger return to the Kuskokwim River. Both the weir and commercial fishery samples followed the same trend of a higher percentage of males early in the run.

Chinook salmon.-The 1993 run of chinook salmon (*N*=1,083) was larger than the 1991 run of 697 (Harper 1995). Females composed a smaller percentage in 1992 (14.8%) than in 1991 (28.8%). By comparison the Kuskokwim River commercial catch was 22.6% females in 1992 and averaged 33.3% between 1985-1992. In addition, the 1992 return of 33.4% to the Kogrukluk River weir (Francisco et al 1993) was over twice as high as the return to the Tuluksak River weir.

Only 160 female chinook salmon were estimated to return in 1992, considerably lower than the 201 in 1991. The potential to misidentify the sex at the weir is low because the fish are bright red, sexually mature, and males have developed a pronounced kype.

The low percentage of females returning to the Tuluksak River is of concern and may be due to several factors. Females return at older ages than males and incur additional years of ocean mortality (Hankin and Healy 1986). The subsistence fishery may also harvest a larger proportion of the females in the run. This fishery allows nets with larger mesh sizes than the commercial fishery. These large mesh nets selectively target large fish, which include older female chinook salmon that predominate the larger sizes (Francisco et al. 1991). Fewer fish and fewer female chinook salmon would reach the Tuluksak River if intensive fishing effort coincided with the run timing of this stock. Walters and Cahoon (1985) have found as fishing has intensified in British Columbia waters, some chinook salmon populations now only persist as remnants. These remnant populations contribute little to the overall spawning populations and the commercial fisheries.

The percentage of gill net marked female chinook salmon in 1992 (19.6%), was higher than the 9.9% in 1991 (Harper 1995). It was also lower than the 1985-92 average (18.84%) found at the Kogrukluk River weir, and lower than the 30% found in 1992 at that location (Francisco et al. 1993). The restriction of the commercial fishery to smaller mesh nets has allowed some larger females to drop out of nets and continue their migration. The lower percentage of gill net marked females in the Tuluksak River may be the result of a higher percentage of the larger females being harvested by the subsistence fishery before reaching the Tuluksak River weir. Data on the sex ratio of subsistence catches from the Kuskokwim River are not available for confirmation.

Pink salmon.-Kuskokwim River pink salmon have strong even year runs (Francisco et al. 1992). Commercial catches in the Kuskokwim River have averaged 3,948 for even years and 217 for odd years since 1980 (Francisco et al. 1992). No escapement goals have been established for pink salmon in the Kuskokwim River drainage.

Sockeye salmon.-The run of sockeye salmon into the Tuluksak River is small. Less than 150 fish passed the weir in 1991 and 1992. The Holitna River, a tributary of the Kuskokwim River above the Tuluksak River, is the only system that has an escapement objective for sockeye salmon. The escapement objectives on that system are 2,000 fish at the Kogrukluk River weir and an aerial survey index of 1,000 fish below the weir (Burkey 1991; Francisco et al. 1992). Additional years of data are needed from the Tuluksak River to determine the stability of the population. Lake habitat that typically supports a large sockeye salmon population is not available in the Tuluksak River drainage.

Coho salmon.-The return of 7,501 coho salmon was larger than the 1991 run of 4,565 (Harper 1995). The weir was pulled from the river each year before completion of the run. Coho salmon may continue to pass the weir site until the end of September or later in small numbers. The decision to pull the weir was based upon the daily escapement falling below 1% of the cumulative passage.

Migration Rates

The migration time for salmon passing through the commercial or test fishery can play an important role in making in-season management decisions. Management can spread the harvest across several fishing periods to prevent the overharvest of individual stocks and allow adequate escapements.

Department tagging studies in 1961, 1962, and 1966 found that chum salmon swimming speeds averaged 19.5 km/d (range 5.4-76.8 km/d) in the Kuskokwim River (Francisco et al. 1992). Fish swimming at these rates would take between 2.2 and 31 days to reach the Tuluksak River weir from Bethel. The Refuge conducted a study in 1989 on chinook salmon and found swimming speeds averaged 13.5 km/d with a range of 0.41-54 km/d (Marino and Otis 1989).

The migration rate using 50% cumulative passage at the test fishery and the weir falls within the range found by others. Estimated swimming speed between the test fishery and the weir for 1992 was 9.4 km/d for chum salmon which was down from 16.9 km/d in

1991 (Harper 1995). Chinook salmon were estimated to swim at the rate of 8.0 km/d down from the 11.3 km/d estimated in 1991. Coho salmon were estimated to swim at 9.4 km/d which was up from the 6.8 km/d in 1991. Sockeye salmon were estimated to swim at 6.8 km/d.

Chum salmon swimming at 9.4 km/d would pass through the lower Kuskokwim River commercial and subsistence fisheries in 17.5 days. A chinook salmon swimming 8 km/d would be vulnerable to harvest for approximately 25 days between the mouth of the Kuskokwim River and the Tuluksak River confluence.

Estimated swimming speeds assume Tuluksak River fish are represented proportionally in test fishery samples. Tuluksak River fish could be on either side of the peak, increasing or decreasing the number of days to reach the weir. The 50% passage method, however, generally estimates lag times between the test fishery and the weir, if the cumulative proportion curves are similar in shape as they were in 1992. If accurate swimming speeds are needed, a tagging study should be conducted. Tagging data may determine spacial and temporal separation of chum and chinook salmon stocks in the lower Kuskokwim River.

The estimate of stream-life above the weir appeared to be acceptable for 1992. Cumulative proportion curves for upstream passage of spawners and downstream passage of carcasses were similar in shape (Figure 5). If the cumulative proportion curves differ substantially, then several factors could be responsible.

Nielson and Geen (1981), found residence time on redds to vary throughout the season. Early arriving salmon generally spend a longer period on a redd than late arrivals. Carcasses have other drawbacks including: rising water levels that wash fish downstream faster than normal, spawning distances above the weir, and carcasses sinking to the bottom above the weir before they are counted. Carcasses, however, represented up to 1/3 of the upstream passage of salmon. A tagging study would provide additional information on stream-life above the weir.

Aerial Survey Timing

Salmon stream-life is important in determining the optimal timing of aerial surveys to gather peak counts. Aerial index surveys must account for stream-life and run timing to provide useful data. Species, like chum salmon, with a short stream-life and protracted escapements should be surveyed more than once and the "Factor 5" or "Area Under the Curve" methods (Cousins et al. 1982) used to estimate total abundance. When 90% of the chum salmon had entered the river, over 60% of the carcasses had been passed downstream. Species with a long stream-life and relatively short immigration time such as chinook salmon can be surveyed once, observing a large percentage of spawners. In the Tuluksak River by July 25, 1992, 91% of the chinook salmon had passed the weir, and 1% of the carcasses had been passed downstream. Surveys flown later would have had a higher percentage of carcasses to subtract from the live counts. The survey flown on July 29 had 94% of the weir counts available for enumeration minus 25% of the carcasses. The optimal time for conducting chinook salmon aerial surveys on the Tuluksak River is the last week of July.

Run data from 1991-1992 suggest the optimal time to conduct aerial surveys for coho salmon would be the first week of September when 70% to 90% of the run have entered the river. Very few carcasses have been counted downstream at that time.

Funding, weather, and water conditions on the Tuluksak River, however, have made it impossible to conduct a single aerial survey for chum, chinook and coho salmon in some years. This emphasizes the need for a better method of estimating escapement.

Recommendations

Based upon the data in this report and personal observations, the following is recommended:

1. Continue the weir operation for at least one full life cycle of chinook salmon. This would be the minimal amount of data used to determine if the low sex ratios for chinook salmon are cyclical. Escapement data from the weir and the intensity of the commercial and subsistence fishery in the Kuskokwim River should be evaluated to determine if the weir is needed as a long term monitoring program.

2. A tagging study should be initiated in the lower Kuskokwim River to gather additional information on salmon migration timing. Data may indicate temporal or spacial separation of various stocks and estimate swimming speeds.

3. Collect spawning and rearing habitat data to quantify the rivers carrying capacity and establish biological escapement goals for chinook, chum and coho salmon.

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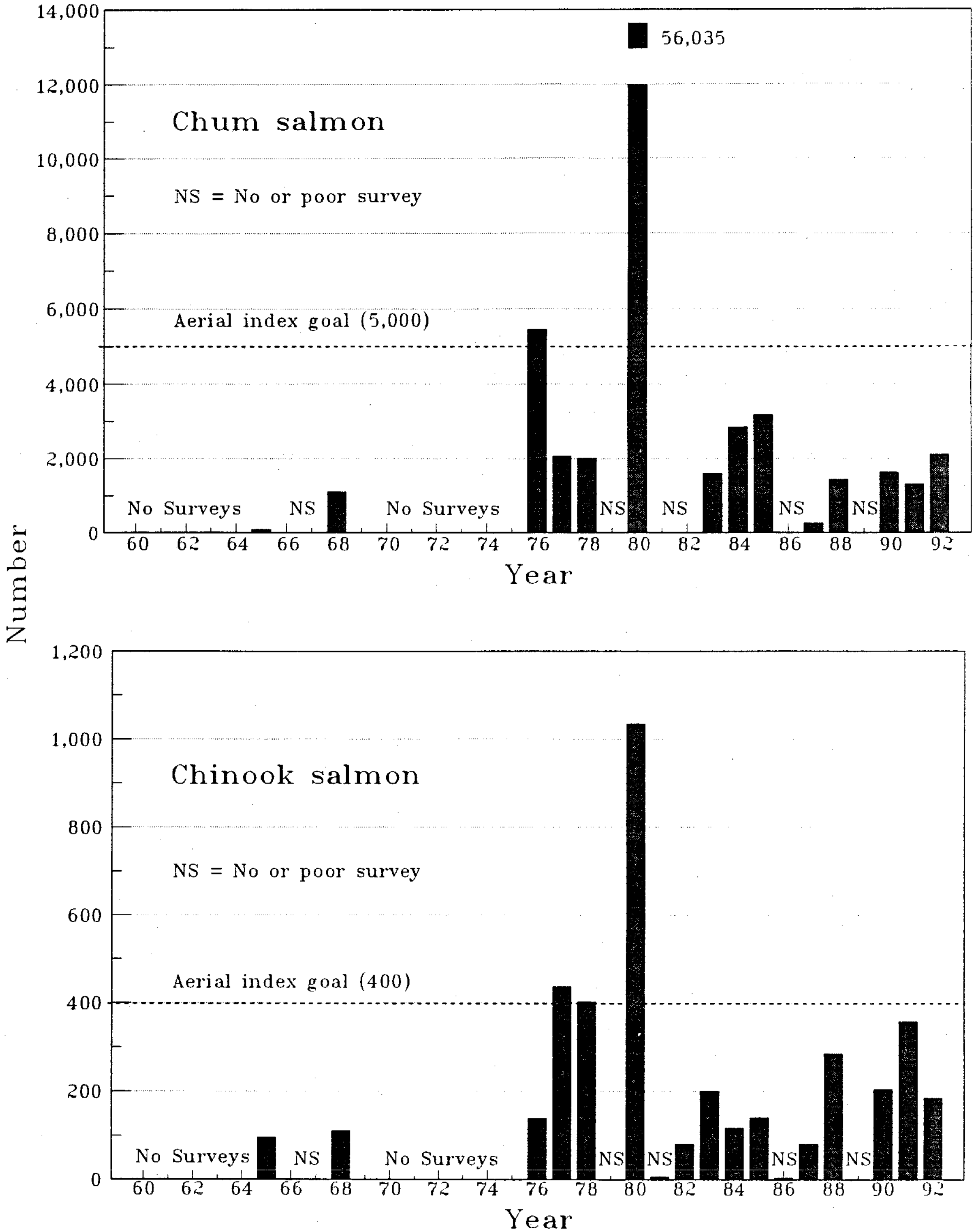

APPENDIX 1.-Aerial index surveys for chinook and chum salmon in the Tuluksak River, 1960-1992.

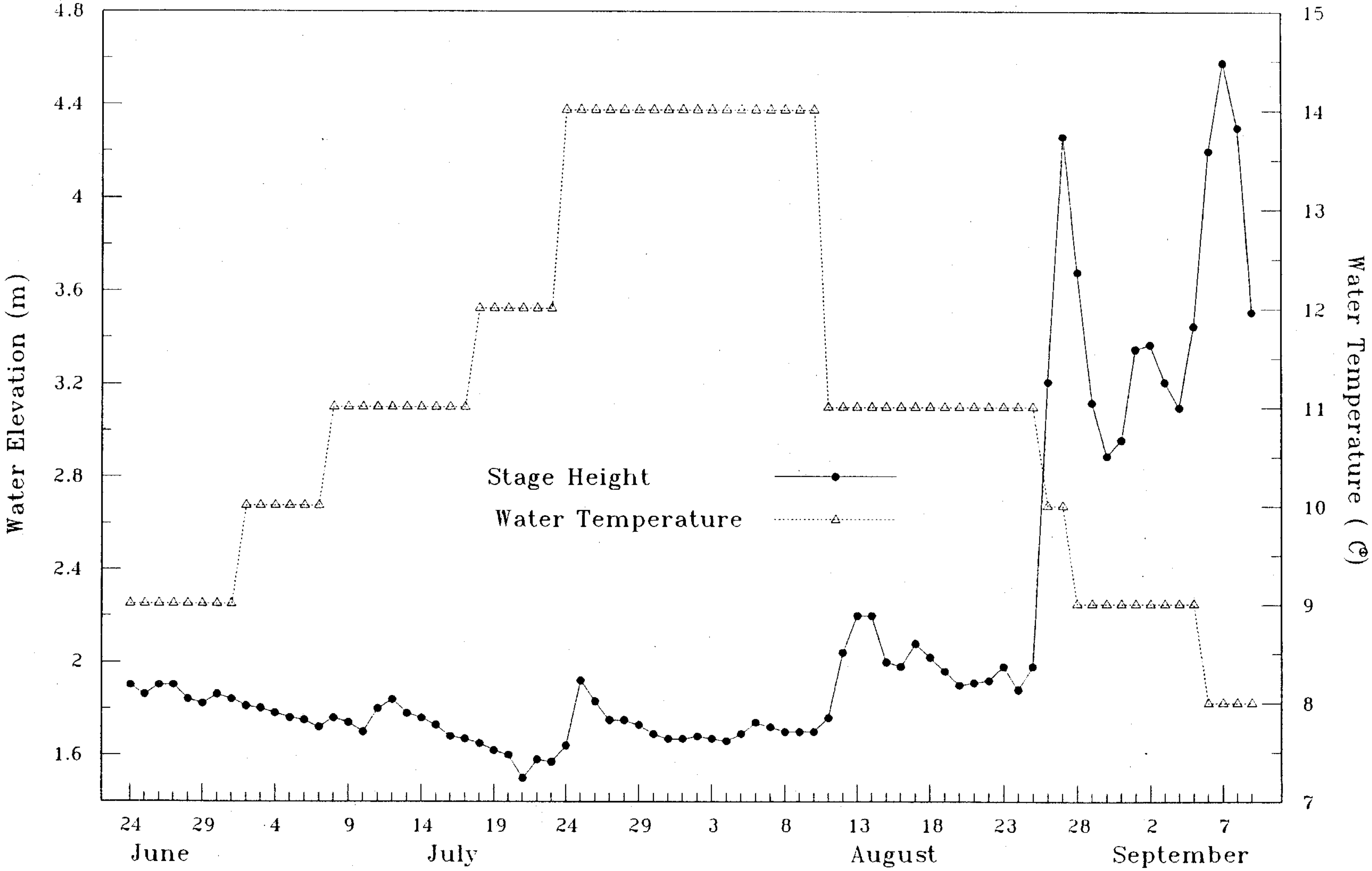

FIGURE 12.–Water levels and temperatures in the Tuluksak River, Alaska, 1992.

APPENDIX 3.–Total daily weir counts of salmon, gill net marked salmon, and resident fish species, Tuluksak River, Alaska, 1992.

					Gill Net Marked								
Date	Chinook salmon	Chum salmon	Sockeye salmon	Pink salmon	Coho salmon	Chinook salmon	Chum salmon	Sockeye salmon	Pink salmon	Coho salmon	Dolly Varden	Whitefish	Arctic Grayling	Northern Pike
06/24	0	1	0	0	0	0	1	0	0	0	0	0	0	0
06/25	0	39	0	0	0	0	16	0	0	0	0	0	0	1
06/26	1	80	0	0	0	1	29	0	0	0	0	0	0	0
06/27	0	75	0	0	0	0	34	0	0	0	1	0	0	0
06/28	2	71	0	0	0	0	39	0	0	0	0	0	0	0
06/29	4	93	0	0	0	1	11	0	0	0	0	0	0	0
06/30	10	170	0	0	0	1	17	0	0	0	3	0	0	0
07/01	15	242	0	0	0	0	21	0	0	0	0	3	1	0
07/02	12	96	0	0	0	1	4	0	0	0	0	0	1	1
07/03	22	155	0	1	0	2	2	0	0	0	0	0	1	0
07/04	85	140	0	0	0	12	13	0	0	0	0	0	0	0
07/05	40	150	0	1	0	2	9	0	0	0	0	0	0	0
07/06	13	107	0	1	0	0	7	0	0	0	1	1	1	0
07/07	28	158	0	1	0	0	3	0	0	0	1	0	0	0
07/08	55	229	0	2	0	3	3	0	0	0	0	0	0	0
07/09	71	228	0	2	0	2	12	0	0	0	0	0	1	0
07/10	117	280	2	3	0	5	2	0	0	0	2	1	0	0
07/11	53	241	1	2	0	5	9	0	0	0	0	0	1	2
07/12	25	202	0	3	0	2	2	0	0	0	2	0	1	0
07/13	32	254	0	3	0	5	7	0	0	0	4	0	1	1
07/14	47	307	2	4	0	9	6	0	0	0	4	0	2	0
07/15	38	418	0	5	0	5	8	0	0	0	6	2	3	0
07/16	32	387	4	9	0	6	7	1	0	0	2	4	0	0
07/17	8	174	1	3	0	0	8	0	0	0	2	0	0	1
07/18	24	510	1	33	0	1	4	0	0	0	3	0	0	0
07/19	27	318	2	21	0	4	8	0	1	0	1	1	2	0
07/20	12	265	2	10	0	1	4	0	0	0	0	1	0	0
07/21	16	260	2	19	0	3	17	0	0	0	0	0	0	0
07/22	40	483	5	17	0	8	14	0	0	0	2	0	0	0
07/23	46	559	20	21	1	5	12	2	0	0	3	2	0	0
07/24	67	664	22	67	1	5	33	1	1	0	9	3	0	0
07/25	44	430	8	60	0	3	13	0	0	0	9	2	3	0
07/26	12	230	3	46	1	0	1	0	0	0	12	1	5	1
07/27	9	263	1	57	0	0	1	0	0	0	8	0	2	0
07/28	8	330	6	43	1	0	8	0	0	0	4	0	0	0
07/29	7	313	4	83	1	0	0	0	0	0	5	2	0	0
07/30	9	200	4	101	4	0	0	1	0	0	4	0	1	0
07/31	5	238	1	126	1	0	3	0	0	0	13	1	3	0
08/01	6	196	4	50	3	1	1	0	0	0	4	0	0	0
08/02	3	211	3	79	3	0	0	0	0	0	5	1	3	0
08/03	4	143	1	43	2	0	0	0	0	0	1	0	0	0
08/04	2	119	0	49	3	0	0	0	0	0	5	0	0	0

APPENDIX 3.–(Continued).

Date	Chinook salmon	Chum salmon	Sockeye salmon	Pink salmon	Coho salmon	Gill Net Marked Chinook salmon	Gill Net Marked Chum salmon	Gill Net Marked Sockeye salmon	Gill Net Marked Pink salmon	Gill Net Marked Coho salmon	Dolly Varden	Whitefish	Arctic Grayling	Northern Pike
08/05	7	137	1	94	20	2	0	0	0	0	3	0	1	0
08/06	4	135	2	104	28	0	0	0	0	0	4	1	0	0
08/07	3	70	2	82	21	0	0	0	0	0	2	0	0	0
08/08	2	117	0	100	11	0	4	0	0	0	2	0	1	0
08/09	1	103	0	145	16	0	0	0	1	0	1	1	0	0
08/10	0	80	2	98	17	0	0	0	2	0	0	0	0	0
08/11	2	97	1	92	42	1	0	0	0	1	0	0	0	0
08/12	0	82	0	201	81	0	0	0	0	0	2	2	0	0
08/13	0	32	0	65	44	0	1	0	0	2	5	0	0	0
08/14	1	33	0	86	121	0	1	0	0	0	3	0	0	1
08/15	1	28	0	46	186	0	0	0	0	2	11	0	0	1
08/16	0	16	1	28	43	0	1	0	0	0	0	0	0	0
08/17	0	30	2	39	80	0	0	0	0	2	2	0	0	0
08/18	1	22	1	47	93	1	0	0	1	1	7	0	0	0
08/19	0	20	1	64	154	0	1	0	0	5	11	1	1	0
08/20	0	22	6	16	64	0	0	0	1	2	0	0	0	0
08/21	2	25	1	36	367	0	0	0	0	13	5	1	2	1
08/22	1	13	2	15	529	1	0	0	0	22	8	0	0	0
08/23	0	18	0	7	318	0	0	0	0	12	6	2	2	0
08/24	0	4	0	6	101	0	0	0	0	4	1	0	1	0
08/25	1	9	1	8	420	0	0	0	0	15	5	0	0	0
08/26	0	8	0	3	246	0	0	0	0	14	1	1	1	0
08/27	0	15	0	21	647	0	0	0	0	23	4	5	8	0
08/28	1	9	0	26	902	1	0	0	0	54	7	20	14	0
08/29	0	6	1	10	448	0	0	0	0	24	6	5	1	1
08/30	2	1	0	10	557	1	0	0	0	39	2	0	3	0
08/31	0	1	0	4	161	0	0	0	0	14	2	2	1	0
09/01	2	2	3	4	174	0	0	0	0	12	2	3	0	0
09/02	1	8	0	14	922	1	1	0	0	78	8	18	0	0
09/03	0	2	1	8	199	0	0	0	0	20	4	7	0	0
09/04	0	0	1	5	105	0	0	0	0	5	1	0	0	0
09/05	0	3	0	7	236	0	0	0	0	29	0	15	1	0
09/06	0	2	1	7	84	0	0	0	0	8	0	0	0	1
09/07	0	1	0	1	18	0	0	0	0	1	0	3	0	0
09/08	0	1	0	3	1	0	0	0	0	0	0	6	0	0
09/09	0	2	0	2	8	0	0	0	0	1	1	4	0	0
09/10	0	0	0	1	16	0	0	0	0	1	0	3	0	0
	1,083	11,183	129	2,470	7,501	101	398	5	7	404	232	125	69	12

APPENDIX 4.–Daily counts and cumulative daily proportions for chum, chinook, sockeye, pink, and coho salmon in the Tuluksak River, Alaska, 1992.

	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
Date	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
06/24	1	0	0	0	0	0	0	0	0	0
06/25	39	0.004	0	0	0	0	0	0	0	0
06/26	80	0.011	1	0.001	0	0	0	0	0	0
06/27	75	0.017	0	0.001	0	0	0	0	0	0
06/28	71	0.024	2	0.003	0	0	0	0	0	0
06/29	93	0.032	4	0.006	0	0	0	0	0	0
06/30	170	0.047	10	0.016	0	0	0	0	0	0
07/01	242	0.069	15	0.030	0	0	0	0	0	0
07/02	96	0.078	12	0.041	0	0	0	0	0	0
07/03	155	0.091	22	0.061	0	0	1	0	0	0
07/04	140	0.104	85	0.139	0	0	0	0	0	0
07/05	150	0.117	40	0.176	0	0	1	0.001	0	0
07/06	107	0.127	13	0.188	0	0	1	0.001	0	0
07/07	158	0.141	28	0.214	0	0	1	0.002	0	0
07/08	229	0.161	55	0.265	0	0	2	0.002	0	0
07/09	228	0.182	71	0.331	0	0	2	0.003	0	0
07/10	280	0.207	117	0.439	2	0.016	3	0.004	0	0
07/11	241	0.228	53	0.488	1	0.023	2	0.005	0	0
07/12	202	0.247	25	0.511	0	0.023	3	0.007	0	0
07/13	254	0.269	32	0.540	0	0.023	3	0.008	0	0
07/14	307	0.297	47	0.584	2	0.039	4	0.009	0	0
07/15	418	0.334	38	0.619	0	0.039	5	0.011	0	0
07/16	387	0.369	32	0.648	4	0.070	9	0.015	0	0
07/17	174	0.384	8	0.656	1	0.078	3	0.016	0	0
07/18	510	0.430	24	0.678	1	0.085	33	0.030	0	0
07/19	318	0.458	27	0.703	2	0.101	21	0.038	0	0
07/20	265	0.482	12	0.714	2	0.116	10	0.042	0	0

APPENDIX 4.–(Continued).

Date	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
07/21	260	0.505	16	0.729	2	0.132	19	0.050	0	0
07/22	483	0.548	40	0.765	5	0.171	17	0.057	0	0
07/23	559	0.598	46	0.808	20	0.326	21	0.066	1	0
07/24	664	0.658	67	0.870	22	0.496	67	0.093	1	0
07/25	430	0.696	44	0.910	8	0.558	60	0.117	0	0
07/26	230	0.717	12	0.922	3	0.581	46	0.135	1	0
07/27	263	0.740	9	0.930	1	0.589	57	0.158	0	0
07/28	330	0.770	8	0.937	6	0.636	43	0.176	1	0.001
07/29	313	0.798	7	0.944	4	0.667	83	0.209	1	0.001
07/30	200	0.816	9	0.952	4	0.698	101	0.250	4	0.001
07/31	238	0.837	5	0.957	1	0.705	126	0.301	1	0.001
08/01	196	0.855	6	0.962	4	0.736	50	0.321	3	0.002
08/02	211	0.873	3	0.965	3	0.760	79	0.353	3	0.002
08/03	143	0.886	4	0.969	1	0.767	43	0.371	2	0.002
08/04	119	0.897	2	0.970	0	0.767	49	0.391	3	0.003
08/05	137	0.909	7	0.977	1	0.775	94	0.429	20	0.005
08/06	135	0.921	4	0.981	2	0.791	104	0.471	28	0.009
08/07	70	0.927	3	0.983	2	0.806	82	0.504	21	0.012
08/08	117	0.938	2	0.985	0	0.806	100	0.545	11	0.013
08/09	103	0.947	1	0.986	0	0.806	145	0.603	16	0.016
08/10	80	0.954	0	0.986	2	0.822	98	0.643	17	0.018
08/11	97	0.963	2	0.988	1	0.829	92	0.680	42	0.023
08/12	82	0.970	0	0.988	0	0.829	201	0.762	81	0.034
08/13	32	0.973	0	0.988	0	0.829	65	0.788	44	0.040
08/14	33	0.976	1	0.989	0	0.829	86	0.823	121	0.056
08/15	28	0.979	1	0.990	0	0.829	46	0.841	186	0.081
08/16	16	0.980	0	0.990	1	0.837	28	0.853	43	0.087
08/17	30	0.983	0	0.990	2	0.853	39	0.868	80	0.097

APPENDIX 4.–(Continued).

Date	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
08/18	22	0.985	1	0.991	1	0.860	47	0.887	93	0.110
08/19	20	0.986	0	0.991	1	0.868	64	0.913	154	0.130
08/20	22	0.988	0	0.991	6	0.915	16	0.920	64	0.139
08/21	25	0.991	2	0.993	1	0.922	36	0.934	367	0.188
08/22	13	0.992	1	0.994	2	0.938	15	0.940	529	0.258
08/23	18	0.993	0	0.994	0	0.938	7	0.943	318	0.301
08/24	4	0.994	0	0.994	0	0.938	6	0.946	101	0.314
08/25	9	0.995	1	0.994	1	0.946	8	0.949	420	0.370
08/26	8	0.995	0	0.994	0	0.946	3	0.950	246	0.403
08/27	15	0.997	0	0.994	0	0.946	21	0.959	647	0.489
08/28	9	0.997	1	0.995	0	0.946	26	0.969	902	0.610
08/29	6	0.998	0	0.995	1	0.953	10	0.973	448	0.669
08/30	1	0.998	2	0.997	0	0.953	10	0.977	557	0.744
08/31	1	0.998	0	0.997	0	0.953	4	0.979	161	0.765
09/01	2	0.998	2	0.999	3	0.977	4	0.981	174	0.788
09/02	8	0.999	1	1	0	0.977	14	0.986	922	0.911
09/03	2	0.999	0	1	1	0.984	8	0.989	199	0.938
09/04	0	0.999	0	1	1	0.992	5	0.991	105	0.952
09/05	3	0.999	0	1	0	0.992	7	0.994	236	0.983
09/06	2	1	0	1	1	1	7	0.997	84	0.994
09/07	1	1	0	1	0	1	1	0.998	18	0.997
09/08	1	1	0	1	0	1	3	0.999	1	0.997
09/09	2	1	0	1	0	1	2	1	8	0.998
09/10	0	1	0	1	0	1	1	1	16	1
	11,183		1,083		129		2,470		7,501	

APPENDIX 5.–Daily counts and cumulative proportion of salmon carcasses counted on the upstream side of the Tuluksak River weir, Alaska, 1992.

	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
Date	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
06/24	0	0	0	0	0	0	0	0	0	0
06/25	1	0	0	0	0	0	0	0	0	0
06/26	0	0	0	0	0	0	0	0	0	0
06/27	1	0.001	0	0	0	0	0	0	0	0
06/28	0	0.001	0	0	0	0	0	0	0	0
06/29	0	0.001	0	0	0	0	0	0	0	0
06/30	0	0.001	0	0	0	0	0	0	0	0
07/01	2	0.001	0	0	0	0	0	0	0	0
07/02	0	0.001	0	0	0	0	0	0	0	0
07/03	2	0.002	0	0	0	0	0	0	0	0
07/04	4	0.003	0	0	0	0	0	0	0	0
07/05	5	0.004	0	0	0	0	0	0	0	0
07/06	5	0.005	0	0	0	0	0	0	0	0
07/07	10	0.008	0	0	0	0	0	0	0	0
07/08	6	0.009	0	0	0	0	0	0	0	0
07/09	35	0.019	0	0	0	0	0	0	0	0
07/10	28	0.026	0	0	0	0	0	0	0	0
07/11	34	0.035	0	0	0	0	0	0	0	0
07/12	30	0.043	0	0	0	0	0	0	0	0
07/13	59	0.058	0	0	0	0	0	0	0	0
07/14	50	0.072	0	0	0	0	0	0	0	0
07/15	44	0.083	0	0	0	0	0	0	0	0
07/16	44	0.095	0	0	0	0	0	0	0	0
07/17	26	0.102	0	0	0	0	0	0	0	0
07/18	69	0.120	1	0.003	0	0	0	0	0	0
07/19	36	0.129	0	0.003	0	0	0	0	0	0
07/20	39	0.139	3	0.012	0	0	0	0	0	0

APPENDIX 5.–(Continued).

Date	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
07/21	30	0.147	0	0.012	0	0	0	0	0	0
07/22	111	0.177	5	0.028	0	0	1	0.001	0	0
07/23	86	0.199	3	0.037	0	0	1	0.001	0	0
07/24	125	0.232	10	0.067	0	0	0	0.001	0	0
07/25	194	0.283	9	0.095	0	0	6	0.006	0	0
07/26	203	0.336	17	0.147	0	0	8	0.012	0	0
07/27	136	0.372	10	0.177	0	0	8	0.017	0	0
07/28	179	0.419	13	0.217	0	0	15	0.028	0	0
07/29	113	0.449	11	0.251	0	0	19	0.042	0	0
07/30	141	0.486	20	0.312	0	0	24	0.060	0	0
07/31	126	0.519	24	0.385	2	0.053	24	0.077	0	0
08/01	109	0.548	24	0.459	0	0.053	20	0.092	0	0
08/02	104	0.575	25	0.535	0	0.053	20	0.106	0	0
08/03	124	0.608	19	0.593	0	0.053	33	0.130	0	0
08/04	112	0.637	21	0.657	0	0.053	23	0.147	0	0
08/05	108	0.666	19	0.716	0	0.053	32	0.170	0	0
08/06	105	0.694	17	0.768	0	0.053	34	0.195	0	0
08/07	108	0.722	13	0.807	2	0.105	38	0.223	0	0
08/08	99	0.748	22	0.875	0	0.105	49	0.259	0	0
08/09	85	0.770	11	0.908	0	0.105	40	0.288	0	0
08/10	82	0.792	5	0.924	1	0.132	48	0.323	0	0
08/11	98	0.818	5	0.939	0	0.132	54	0.362	0	0
08/12	96	0.843	7	0.960	3	0.211	55	0.402	0	0
08/13	87	0.866	5	0.976	0	0.211	28	0.422	0	0
08/14	67	0.883	3	0.985	2	0.263	41	0.452	0	0
08/15	66	0.901	1	0.988	1	0.289	51	0.489	0	0
08/16	65	0.918	1	0.991	1	0.316	60	0.533	0	0
08/17	51	0.931	2	0.997	0	0.316	72	0.586	0	0

APPENDIX 5.–(Continued).

	Chum salmon		Chinook salmon		Sockeye salmon		Pink salmon		Coho salmon	
Date	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion	N	Cumulative Proportion
08/18	54	0.946	0	0.997	2	0.368	79	0.643	0	0
08/19	41	0.956	0	0.997	6	0.526	80	0.701	0	0
08/21	31	0.964	0	0.997	3	0.605	64	0.748	0	0
08/22	19	0.969	0	0.997	0	0.605	65	0.795	0	0
08/23	23	0.976	0	0.997	4	0.711	66	0.843	0	0
08/24	17	0.980	0	0.997	3	0.789	54	0.883	0	0
08/25	18	0.985	0	0.997	1	0.816	54	0.922	0	0
08/26	19	0.990	0	0.997	1	0.842	39	0.950	0	0
08/27	6	0.991	0	0.997	1	0.868	21	0.966	0	0
08/28	4	0.992	0	0.997	0	0.868	3	0.968	0	0
08/29	1	0.993	0	0.997	0	0.868	6	0.972	0	0
08/30	5	0.994	0	0.997	1	0.895	4	0.975	1	0.25
08/31	2	0.994	0	0.997	0	0.895	6	0.980	0	0.25
09/01	4	0.996	0	0.997	1	0.921	12	0.988	0	0.25
09/02	4	0.997	0	0.997	1	0.947	4	0.991	1	0.50
09/03	5	0.998	0	0.997	0	0.947	5	0.995	1	0.75
09/04	3	0.999	0	0.997	0	0.947	4	0.998	1	1
09/05	5	1	1	1	1	0.974	3	1	0	1
09/06	0	1	0	1	1	1	0	1	0	1
09/07	0	1	0	1	0	1	0	1	0	1
09/08	0	1	0	1	0	1	0	1	0	1
09/09	0	1	0	1	0	1	0	1	0	1
09/10	0	1	0	1	0	1	0	1	0	1
Total	3,801		327		38		1,373		4	

Appendix 6. - Estimated age and sex composition of weekly chum salmon passage and results from Z-test comparing age composition between the sexes from the Tuluksak River, Alaska, 1992.

		Brood Year and Age Group				
		1989	1988	1987	1986	
		0.2	0.3	0.4	0.5	TOTAL
Stratum Dates:	WEEK 26					
Sampling Dates:	6/24 - 27					
Sample Size:	120					
Female	Percent of Sample	0.8	10.0	15.8	0.0	26.7
	Number in Passage	2	20	31	0	52
Male	Percent of Sample	10.0	5.8	56.7	0.8	73.3
	Number in Passage	20	11	111	2	143
Total	Percent of Sample	10.8	15.8	72.5	0.8	100.0
	Number in Passage	21	31	141	2	195
	Standard Error	6	7	8	2	
Stratum Dates:	WEEK 27					
Sampling Dates:	6/28 - 7/4					
Sample Size:	160					
Female	Percent of Sample	0.0	9.4	16.9	0.0	26.3
	Number in Passage	0	91	163	0	254
Male	Percent of Sample	0.0	18.1	51.9	3.8	73.8
	Number in Passage	0	175	502	36	713
Total	Percent of Passage	0.0	27.5	68.8	3.8	100.0
	Number in Catch	0	266	665	36	967
	Standard Error	0	34	36	15	
Stratum Dates:	WEEK 28					
Sampling Dates:	7/5 - 11					
Sample Size:	160					
Female	Percent of Sample	1.9	17.5	24.4	1.3	45.0
	Number in Passage	26	244	340	17	627
Male	Percent of Sample	3.1	16.3	35.0	0.6	55.0
	Number in Passage	44	226	488	9	766
Total	Percent of Sample	5.0	33.8	59.4	1.9	100.0
	Number in Passage	70	470	827	26	1,393
	Standard Error	24	52	54	15	
Stratum Dates:	WEEK 29					
Sampling Dates:	7/12 - 18					
Sample Size:	160					
Female	Percent of Sample	0.0	20.6	16.9	0.6	38.1
	Number in Passage	0	465	380	14	859
Male	Percent of Sample	0.0	21.3	37.5	3.1	61.9
	Number in Passage	0	479	845	70	1394
Total	Percent of Sample	0.0	41.9	54.4	3.8	100
	Number in Passage	0	943	1,225	85	2252
	Standard Error	0	88	89	34	

Appendix 6. - (Continued).

		Brood Year and Age Group				
		1989	1988	1987	1986	
		0.2	0.3	0.4	0.5	TOTAL
Stratum Dates:	WEEK 30					
Sampling Dates:	7/19 - 25					
Sample Size:	200					
Female	Percent of Sample	1.0	32.0	21.5	0.0	54.5
	Number in Passage	30	953	640	0	1,624
Male	Percent of Sample	0.0	22.0	20.5	3.0	45.5
	Number in Passage	0	655	611	89	1,355
Total	Percent of Sample	1.0	54.0	42.0	3.0	100.0
	Number in Passage	30	1,609	1,251	89	2,979
	Standard Error	21	105	104	36	
Stratum Dates:	WEEK 31					
Sampling Dates:	7/26 - 8/1					
Sample Size:	160					
Female	Percent of Sample	0.6	43.1	19.4	0.0	63.1
	Number in Passage	11	763	343	0	1,118
Male	Percent of Sample	0.6	24.4	11.2	0.6	36.8
	Number in Passage	11	432	198	11	652
Total	Percent of Sample	1.3	67.5	30.6	0.6	100.0
	Number in Passage	22	1,195	541	11	1,770
	Standard Error	16	66	65	11	
Stratum Dates:	WEEK 32					
Sampling Dates:	8/2 - 8					
Sample Size:	141					
Female	Percent of Sample	2.8	43.3	14.2	0.0	60.3
	Number in Passage	26	403	132	0	562
Male	Percent of Sample	0.0	30.5	9.2	0.0	39.7
	Number in Passage	0	284	86	0	370
Total	Percent of Sample	2.8	73.8	23.4	0.0	100.0
	Number in Passage	26	687	218	0	932
	Standard Error	13	35	33	0	
Stratum Dates:	WEEK 33					
Sampling Dates:	8/9 - 15					
Sample Size:	172					
Female	Percent of Sample	3.5	58.1	10.5	0.0	72.1
	Number in Passage	16	265	48	0	328
Male	Percent of Sample	0.0	23.3	4.7	0.0	27.9
	Number in Passage	0	106	21	0	127
Total	Percent of Sample	3.5	81.4	15.1	0.0	100.0
	Number in Passage	16	370	69	0	455
	Standard Error	6	14	12	0	

Appendix 6. - (Continued).

		Brood Year and Age Group				
		1989	1988	1987	1986	
		0.2	0.3	0.4	0.5	TOTAL
Stratum Dates:	WEEK 34 - 37					
Sampling Dates:	8/16 - 9/10					
Sample Size:	24					
Female	Percent of Sample	3.6	57.7	11.2	0.0	72.4
	Number in Passage	9	138	27	0	174
Male	Percent of Sample	0.0	23.5	4.1	0.0	27.6
	Number in Passage	0	56	10	0	66
Total	Percent of Sample	3.6	81.1	15.3	0.0	100.0
	Number in Passage	9	195	37	0	240
	Standard Error	9	20	18	0	
Stratum Dates:	SEASON					
Sampling Dates:	6/24- 9/10					
Sample Size:	1,297					
Female	Percent of Sample	1.1	29.9	18.8	0.3	50.0
	Number in Passage	120	3,341	2,104	32	5,597
Male	Percent of Sample	0.7	21.7	25.7	1.9	50.0
	Number in Passage	74	2,425	2,870	218	5,587
Total	Percent of Sample	1.7	51.6	44.5	2.2	100.0
	Number in Passage	194	5,766	4,974	249	11,184*
	Standard Error	40	170	170	55	

* rounding error, total = 11,183

Z-test statistic of age composition difference between sexes.

Proportion Male	a	0.02	0.60	0.38	0.01
V(Proportion males)	b	3.53E-05	1.12E-03	7.50E-04	1.12E-05
Proportion Female	a	0.01	0.43	0.51	0.04
V(Proportion females)	b	1.69E-05	8.57E-04	9.46E-04	8.73E-05
Z-test statistic		1.12	3.67	-3.35	-3.36
P	c	0.263	0.000	0.001	0.001

a Proportion within sex

b V= variance for age proportions within each sex
Z=test statistic

c P value. Z was significant at alpha=0.05 if P was less than the Bonferroni adjusted level of 0.0125.

Appendix 7.-Estimated age and sex composition of weekly chinook salmon passage and results from Z-test comparing age composition between the sexes from the Tuluksak River, Alaska, 1992.

		Brood Year and Age Group								
		1989	1988	1987		1986		1985		
		1.1	1.2	1.3	2.2	1.4	2.3	1.5	2.4	TOTAL
Stratum Dates:	WEEKS 26 -27									
Sampling Dates:	6/21 - 7/4									
Sample Size:	132									
Female	Percent of Sample	0.0	4.6	4.6	0.0	14.4	0.0	2.3	0.0	25.8
	Number in Passage	0	7	7	0	22	0	3	0	39
Male	Percent of Sample	2.3	22.0	43.9	0.0	5.3	0.0	0.8	0.0	74.2
	Number in Passage	3	33	66	0	8	0	1	0	112
Total	Percent of Sample	2.3	26.5	48.5	0.0	19.7	0.0	3.0	0.0	100.0
	Number in Passage	3	40	73	0	30	0	5	0	151
	Standard Error	2	6	7	0	5	0	2	0	
Stratum Dates:	WEEK 28									
Sampling Dates:	7/5 - 11									
Sample Size:	136									
Female	Percent of Sample	0.0	0.0	2.2	0.0	5.9	0.0	2.2	0.0	10.3
	Number in Passage	0	0	8	0	22	0	8	0	39
Male	Percent of Sample	8.8	50.0	30.2	0.0	0.7	0.0	0.0	0.0	89.7
	Number in Passage	33	189	114	0	3	0	0	0	338
Total	Percent of Sample	8.8	50.0	32.4	0.0	6.6	0.0	2.2	0.0	100.0
	Number in Passage	33	189	122	0	25	0	8	0	377
	Standard Error	9	16	15	0	8	0	5	0	
Stratum Dates:	WEEK 29									
Sampling Dates:	7/12 - 18									
Sample Size:	139									
Female	Percent of Sample	0.0	0.7	1.4	0.0	12.2	0.0	0.7	0.0	15.1
	Number in Passage	0	1	3	0	25	0	1	0	31
Male	Percent of Sample	7.9	41.0	24.5	0.0	10.1	0.7	0.7	0.0	84.9
	Number in Passage	16	84	50	0	21	1	1	0	175
Total	Percent of Sample	7.9	41.7	25.9	0.0	22.3	0.7	1.4	0.0	100.0
	Number in Passage	16	86	53	0	46	1	3	0	206
	Standard Error	5	9	8	0	7	1	2	0	
Stratum Dates:	WEEK 30 -36									
Sampling Dates:	7/19 - 9/5									
Sample Size:	129									
Female	Percent of Sample	0.0	0.0	3.1	0.0	11.6	0.0	0.0	0.0	14.7
	Number in Passage	0	0	11	0	40	0	0	0	51
Male	Percent of Sample	13.2	28.7	27.1	7.8	7.8	0.8	0.0	0.0	85.3
	Number in Passage	46	100	95	27	27	3	0	0	298
Total	Percent of Sample	13.2	28.7	30.2	7.8	19.4	0.8	0.0	0.0	100.0
	Number in Passage	46	100	106	27	68	3	0	0	349
	Standard Error	10	14	14	8	12	3	0	0	
Stratum Dates:	SEASON									
Sampling Dates:	6/21-9/5									
Sample Size:	536									
Female	Percent of Sample	0.0	0.8	2.7	0.0	10.1	0.0	1.2	0.0	14.8
	Number in Passage	0.0	8.4	29.0	0.0	109.6	0.0	13.3	0.0	160
Male	Percent of Sample	0.1	0.4	30.0	2.5	5.4	0.4	0.2	0.0	85.2
	Number in Passage	99.0	406.2	325	27	59	4	3	0	923
Total	Percent of Sample	0.1	1.1	32.7	2.5	15.5	0.4	1.6	0.0	100.0
	Number in Passage	99	415	354	27	168	4	16	0	1,083
	Standard Error	15	24	23	8	17	3	6	0	
	Proportion Male *a*	0.00	0.05	0.18	0.00	0.68	0.00	0.06	0.00	
	V(Proportion males) *b*	0.0E+00	4.1E-04	2.8E-03	0.0E+00	1.4E-02	0.0E+00	1.2E-03		
	Proportion Female *a*	0.11	0.44	0.35	0.03	0.06	0.00	0.00	0.00	
	V(Proportion females) *b*	2.6E-04	7.3E-04	6.4E-04	8.0E-05	1.3E-04	1.1E-05	4.1E-06		
	Z	-6.625	-11.506	-2.904	-3.273	5.312	-1.360	2.302		
	P *c*	0.0000	0.0000	0.0037	0.0011	0.0000	0.1740	0.0214		

a Proportion within sex
b V= variance for age proportions within each sex
Z=test statistic
c P value. Z was significant at alpha 0.05 if P was less than Bonferroni adjustment level of 0.007

Appendix 8. - Estimated age and sex composition of sockeye salmon passage from the Tuluksak River, River, Alaska, 1992.

		Brood Year and Age Group								
		1989	1988		1987			1986		
		0.2	0.3	1.2	0.4	1.3	2.2	1.4	2.3	Total
Stratum Dates:	SEASON									
Sampling Dates:	7/5 - 8/29									
Sample Size:	29									
Female	Percent of Sample	0.4	4.1	5.5	0.7	46.1	0.7	2.6	1.9	56.8
	Number in Passage	0	5	7	1	60	1	3	2	80
Male	Percent of Sample	0.4	1.5	7.0	0.7	25.1	0.7	1.1	1.9	34.7
	Number in Passage	0	2	9	1	32	1	1	2	49
Total	Percent of Sample	0.7	5.5	12.6	1.4	71.2	1.5	3.7	3.7	91.5
	Number in Passage	1	7	16	2	92	2	5	5	129
	Standard Error	2	6	8	3	11	3	5	5	

Appendix 9. - Estimated age and sex composition of weekly coho salmon passage and results from Z-test comparing age composition between the sexes from the Tuluksak River , Alaska, 1992.

		Brood Year and Age Group			
		1989	1988	1987	
		1.1	2.1	3.1	Total
Stratum Dates:	WEEKS 30 - 32				
Sampling Dates:	7/19 - 8/8				
Sample Size:	29				
Female	Percent of Sample	3.5	62.1	3.5	69.0
	Number in Passage	3	63	3	70
Male	Percent of Sample	3.5	24.1	3.5	31.0
	Number in Passage	3	24	3	31
Total	Percent of Sample	6.9	86.2	6.9	100.0
	Number in Passage	7	87	7	101
	Standard Error	5	7	5	
Stratum Dates:	WEEK 33				
Sampling Dates:	8/9 - 15				
Sample Size:	150				
Female	Percent of Sample	2.7	34.7	6.0	43.3
	Number in Passage	14	176	30	220
Male	Percent of Sample	6.0	45.3	5.3	56.7
	Number in Passage	30	230	27	287
Total	Percent of Sample	8.7	80.0	11.3	100.0
	Number in Passage	44	406	57	507
	Standard Error	12	17	13	
Stratum Dates:	WEEK 34				
Sampling Dates:	8/16 - 22				
Sample Size:	97				
Female	Percent of Sample	0.0	35.1	3.1	38.1
	Number in Passage	0	466	41	507
Male	Percent of Sample	7.2	46.4	8.3	61.9
	Number in Passage	96	617	110	823
Total	Percent of Sample	7.2	81.4	11.3	100.0
	Number in Passage	96	1,083	151	1,330
	Standard Error	35	53	43	
Stratum Dates:	WEEK 35				
Sampling Dates:	8/23 - 29				
Sample Size:	98				
Female	Percent of Sample	1.0	32.7	10.2	43.9
	Number in Passage	31	1,006	314	1,352
Male	Percent of Sample	4.1	36.7	15.3	56.1
	Number in Catch	126	1,132	472	1,730
Total	Percent of Sample	5.1	69.4	25.5	100.0
	Number in Passage	157	2,138	786	3,082
	Standard Error	69	144	136	

Appendix 9. - (Continued).

		Brood Year and Age Group			
		1989	1988	1987	
		1.1	2.1	3.1	Total
Stratum Dates:	WEEKS 36 - 37				
Sampling Dates:	8/30 - 9/10				
Sample Size:	99				
Female	Percent of Sample	4.0	36.4	8.1	48.5
	Number in Passage	100	902	200	1,203
Male	Percent of Sample	3.0	42.4	6.1	51.5
	Number in Passage	75	1,052	150	1,278
Total	Percent of Sample	7.1	78.8	14.1	100.0
	Number in Passage	167	1,955	351	2,481
	Standard Error	64	102	87	
Stratum Dates:	SEASON				
Sampling Dates:	7/19- 9/5				
Sample Size:	473				
Female	Percent of Sample	2.0	34.8	7.9	44.7
	Number in Passage	149	2,613	590	3,352
Male	Percent of Sample	4.4	40.7	10.2	55.3
	Number in Passage	331	3,056	762	4,149
Total	Percent of Sample	6.4	75.6	18.0	100.0
	Number in Passage	167	5,669	1,352	7,501
	Standard Error	101	185	168	

Z-test statistic of age composition difference between sexes.

Proportion Male	*a*	0.044	0.780	0.176
V(Proportion males)	*b*	3.5E-04	1.2E-02	1.7E-03
Proportion Female	*a*	0.080	0.736	0.184
V(Proportion	*b*	4.9E-04	7.5E-03	1.4E-03
Z		-1.218	0.307	-0.140
P	*c*	0.0125	0.1439	0.1975

a Proportion within sex
b V=variance for age proportions within each sex
Z=test statistic
c P value. Z was significant at the alpha =0.05 if P was less than the Bonferroni adjusted level of 0.017